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INDEX

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ROBERT W HUNT.

CASSIER'S MAGAZINE.

VOL. IV. MAY, 1893. No. 19.

FAST TRAINS OF ENGLAND AND AMERICA.

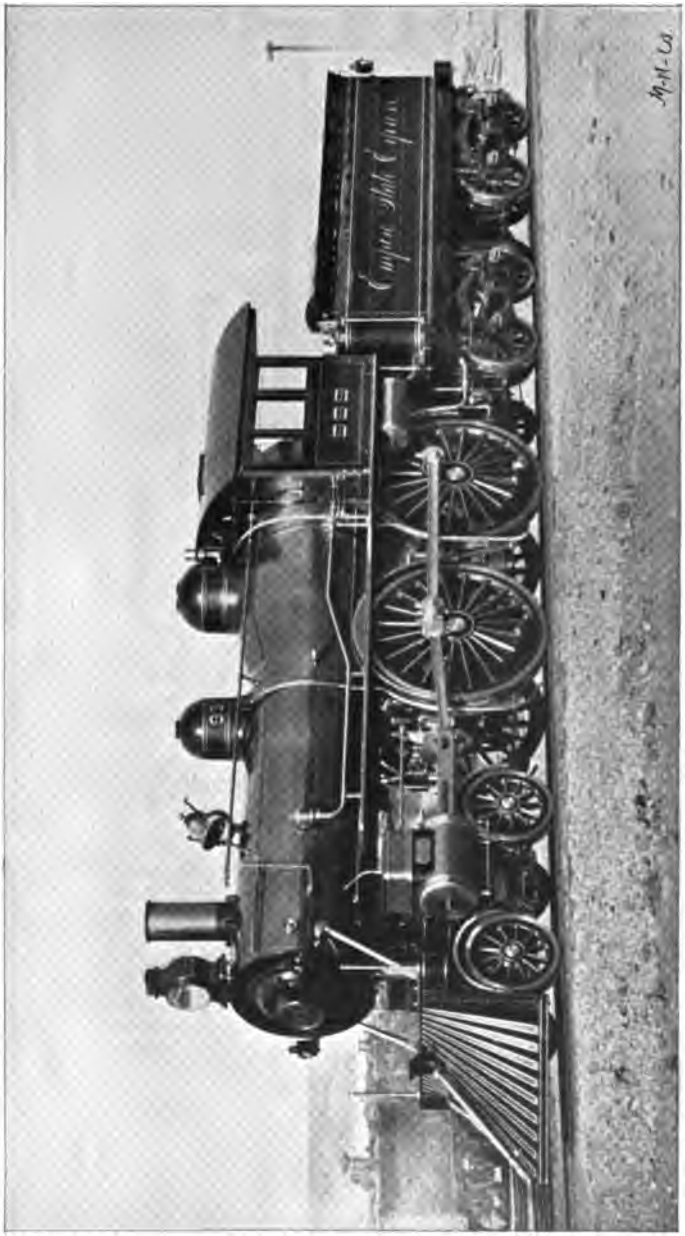
By G'r Lodian.

THE railroad motto of the present time is speed—increasing speed. In the transport of passengers, of mails, of live stock, or of merchandise, speed is the great object held in view; for speed has a golden significance—money, economy. The hurry of this fin de siécle period has never better illustrated anything than the fitness of that trite saying, "Time is money," and in the railroads of today its realization has been closely approached, if not actually attained. How true this is can be best shown by a review of the fast trains of the two countries pre-eminent in railroad engineering—Great Britain and the United States.

As one of the foremost examples of high speed trains may well be taken the Empire State Express of the New York Central and Hudson River Railroad. The locomotives hauling this train belong to what is known as the "800 class," and weigh when loaded ready for duty 126,150 pounds, of which 81,400 pounds come on the four driving wheels, leaving 44,750 on the front truck. These engines have been very successful from the start, having good steaming capacity, and almost as much hauling power as some of the ten-wheel express engines used in the western part of the United States.

The Empire State Express maintains a greater long distance speed than any other train in the world. From New York to Buffalo, a distance of 440 miles, the schedule time is eight hours and forty minutes, which, including four stops—two of five minutes each to change engines—gives an average speed of 50.7 miles an hour. On the British Great Northern road the London-Grantham, 105¼ mile run, on the other hand, is made in 115 minutes without stopping, and with the engine hauling a hundred tons more than on the New York Central. This run is not a recent accomplishment, but was initiated about twelve years ago. The average speed attained is nearly fifty-five miles an hour, the rate over a large portion of the run exceeding sixty miles an hour.

It is interesting to note here, however, that a new and still larger engine has been built to haul the New York Central road's crack train. An illustration of this new locomotive is shown on another page. This engine which is expected to beat all previous records, is known as "No. 999," and resembles the engines of the "800 class" in all essential features except size. The size of the cylinders



LOCOMOTIVE USED ON EMPIRE STATE EXPRESS BETWEEN NEW YORK AND BUFFALO. THE FASTEST REGULAR LONG DISTANCE TRAIN IN THE WORLD.

FROM ILLUSTRATED BUFFALO EXPRESS. COPYRIGHT 1893, BY GEO. E. MATTHEWS & CO.

has remained unchanged, being nineteen inches in diameter by twenty-four inches stroke. The truck wheels are forty inches in diameter, and the total wheel base measures twenty-three feet eleven inches. The boiler here, too, is of the wagon top type. The fire box is 108 inches long and 40⅞ inches wide. The total heating surface is 1930 square feet, and the grate area amounts to 30.7 square feet. The tender has a capacity of 6¾ tons, and carries 3587 gallons of water.

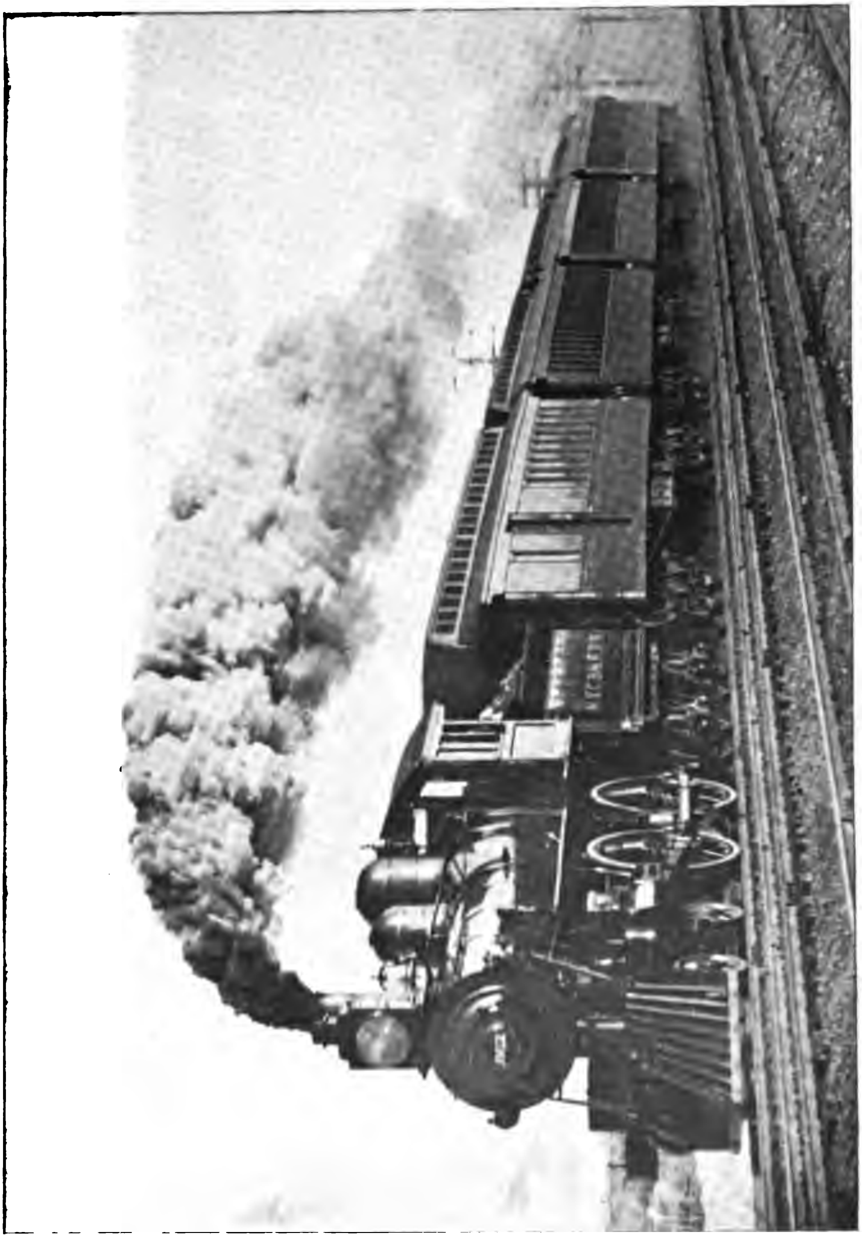
The principal dimensions of the locomotives regularly used are as follows:

Diam. of cylinder and stroke of piston....	19 in. diam. × 24 in. stroke.
Diam. of driving wheels outside of tire................	78 in. Tire held by shrinkage and retaining rings.
Diam. and length of driving axle journal.	8½ in. diam. × 10½ in. long.
Diam. engine truck wheels...........	36 in.
Diam. and length of engine truck axle journals...........	6 in. diam. × 10 in. long.
Working steam pressure................	180 lbs. per sq. in.
Style of boiler.......	Wagon top.
Diam of first ring outside...............	58 in.
Size of firebox inside.	Length, 96 3/16 in.; width, 40⅞ in.; depth, F. 70¼ in., B. 58¼ in.
Tubes, material......	Charcoal iron.
" number of....	268.
Tubes, outside diameter..............	2 in.
Tubes, length over tube sheets........	12 ft.
Heating surface tubes	1,670.7 sq. ft.
Heating surface firebox...............	147.7 "
Heating surface total.	1,818.4 "
Grate surface........	27.3 "
Weight of tender, empty.............	38,600 lbs.
Wheels, number of...	8
Wheels, diam........	36 in.
Water capacity.......	3,500 gallons.
Coal capacity........	6¾ tons.
Total length of engine and tender.........	57 ft., 1⅜ in.
Total weight of engine in working order...	126,150 lbs.
Total weight on drivers............	81,400 lbs.
Total wheel base.....	23 ft., 11 in.
Driving wheel base...	8 ft., 6 in.
Rigid wheel base.....	8 ft., 6 in.
Fuel used...........	Bituminous coal.

For more convenient comparison with the Empire State Express the main dimensions of the new engine are again given in tabulated form :

Cylinders....................	19 in. × 24 in.
Diam. of driving wheels outside of tires.............	86 in.
Diam. engine truck wheels..	40 in.
Springs, length of driver, centre to centre of hangers..	44 in.
Total length of boiler........	26 ft., 4⅛ in.
Diam. of first ring outside....	58 in.
Size of firebox..............	108¾ in. × 40⅞ in.
Tubes, 268..................	2 in. dia., 12 ft. long.
Heating surface in tubes	1697.45 sq. ft.
" " " fire box..	232.92 sq. ft.
Total heating surface........	1930.37 sq. ft.
Grate surface................	30.7 sq. ft.
Stack, inside diam..........	15¼ in.
Weight in working order	124,000 lbs.
Weight on drivers...........	84,000 lbs.
Driving wheel base...	8 ft., 6 in.
Weight of tender loaded....	80,000 lbs.
Total weight of engine and tender..................	204,000 lbs.
Extreme length of engine....	39 ft., 6¾ in.
Extreme height from top of rails to top of stack......	14 ft., 10 in.

While this engine, as already intimated, is expected to appreciably exceed the already most remarkable long-distance performances recorded on the New York Central road, the fastest one-mile record, according to all accounts, belongs to the Central Railroad of New Jersey. Particulars of the rather unpretentious looking engine with which this record has been gained will be of interest in this connection. The engine is of the compound type, with cylinders thirteen and twenty-two inches in diameter by twenty-four inch stroke. The drivers measure seventy-eight inches in diameter ; driving wheel base, seven feet six inches ; total wheel base twenty-two feet three and one-half inches. The boiler is fifty-eight inches in diameter, and has 250 two-inch tubes, eleven feet ten inches long. The total weight of the engine is 123,800 pounds, of which 88,400 come on the drivers. The tender has a capacity for 3500 gallons of water. In one of the trial runs made from Philadelphia to Jersey City with the compound



THE EMPIRE STATE EXPRESS, RUNNING BETWEEN NEW YORK AND BUFFALO—THE FASTEST TRAIN IN THE WORLD.

engine No. 385, the train hauled weighed about 140 tons. The weight of locomotive and tender together amounted to 102 tons. Philadelphia was left at 5.15 P. M., and the train ran at the rate of forty miles per hour to Wayne Junction, which was reached at 5.26. At 5.29 the train again started on the eighty-five-mile stretch to Jersey City. At Tabor Junction the train was slowed down, and near Jenkintown it was flagged. The up-hill grade is there seventy-eight feet to the mile, but still five miles were covered in four minutes. On toward Langhorne, thirteen miles distant, the schedule time was fourteen minutes, one mile of the distance, however, being made in forty-four seconds. From Somerton to Parkland, five miles, was made in forty-two, forty-one, forty, forty and forty-two seconds respectively, the hourly rate of speed thus varying from eighty-six to ninety miles. The five miles were passed over in three minutes and twenty-five seconds. Langhorne was reached at 5.51, the thirteen-mile stretch having been covered in twelve minutes. The best time for one mile on this section was thirty-nine seconds. Further on the way, to Plainfield, no noteworthy speed was made, but there were, instead, several delays. From Plainfield on, however, the world's record was to be broken. Leaving Plainfield at 6.57 (three minutes late), Fanwood was passed, and beyond this point the chronograph recorded a mile in thirty-seven seconds, and another one in thirty-eight seconds, the hourly rate of speed being ninety-seven miles. Jersey City was reached two minutes ahead of time. A boiler pressure of 180 pounds was carried. The track, it should be remarked, was in favorable condition, there having been a heavy downpour of rain along the line.

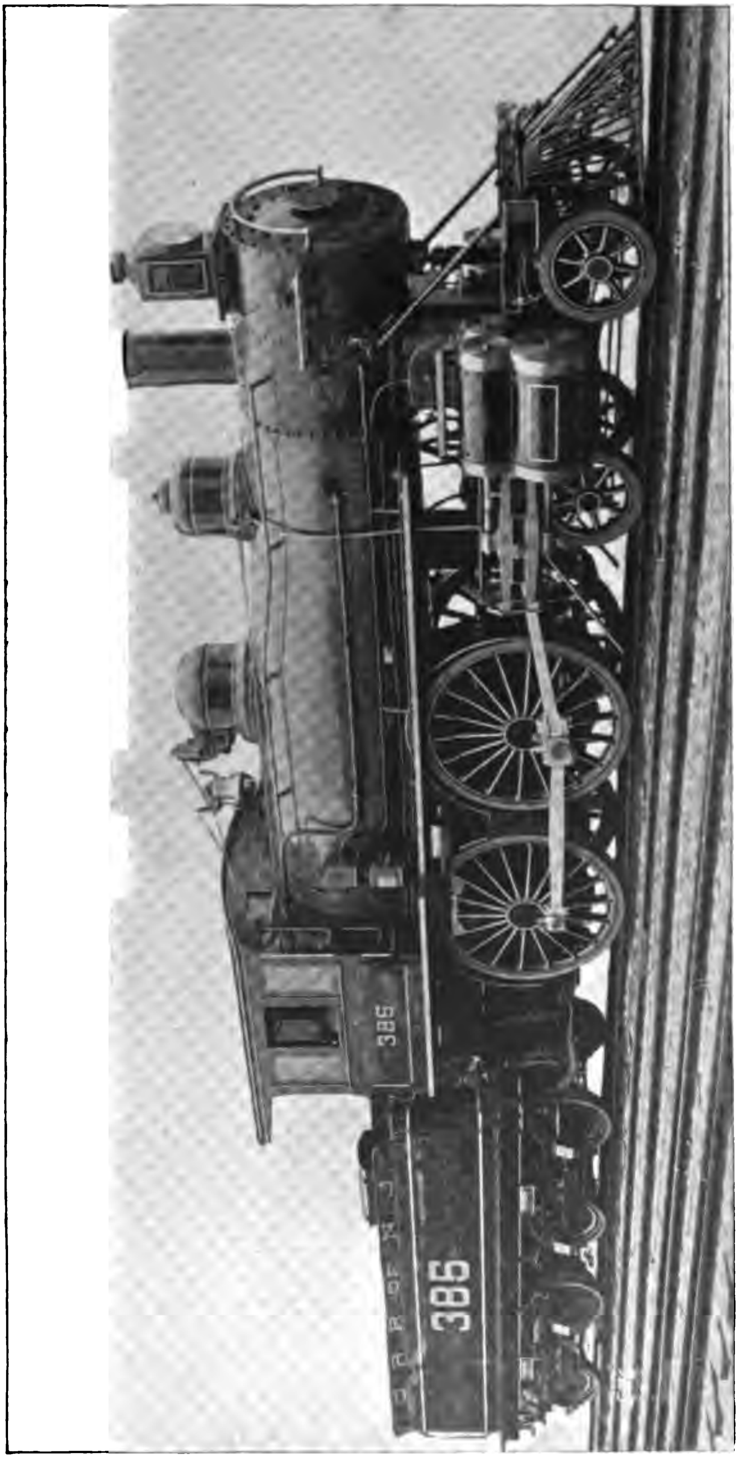
Locomotives of this type are used to haul the Royal Blue Line trains part of the way between Jersey City, N. J., and Washington, D. C., a distance of 224.5 miles. This line is a through express service over the Baltimore and Ohio and Philadelphia and Reading Railroads, and the Central Railroad of New Jersey, making the distance in five hours, including the ferry New York to Jersey City. The train is scheduled to

Leave	New York..at	11.30 A. M.	
"	Jersey City..at	11.42 A. M.	
"	Elizabeth...at	11.58 A. M.	10.06 miles
"	Wayne Junc.at	1.20 P. M.	86.07 "
"	Philadelphia at	1.35 P. M.	93.07 "
"	Wil'ington..at	2.05 P. M.	118.08 "
"	Baltimore...at	3.45 P. M.	193.07 "
Arrive	Washington.at	4.30 P. M.	233.07 "

The average speed, including regular stops and other sources of detention, is forty-five miles per hour, but to maintain this average and to make up for the detentions and six stops, a speed of more than sixty miles per hour is made over the more favorable portions of the route.

The celebrated fast run from London to Grantham, a distance of 105¼ miles, on the Great Northern Railway, England, is made several times daily in one hour and fifty-five minutes without stops. That is the best speed for two or three of the trains each way; the others take from five to eight minutes longer (with stops). The engines used have ninety-seven inch drivers, and eighteen by twenty-eight inch cylinders. The weight of engine and tender in working order is eighty-five and one-half tons. The weight of water carried for the run exceeds fifteen and one-half tons, while the coal amounts to about five tons.

The usual weight of the six-wheeled Great Northern car is fifteen tons. In winter the trains consist of twelve cars, making, altogether, 180 tons. In summer the trains are made of sixteen cars, amounting to 240 tons in weight, not counting the weight of passengers and baggage. Whatever the weight, however, the trains must be hauled unaided and run on time. No pilot is allowed. It is of interest to compare these trains with the 143-ton crack American trains with engines burning about twice as much coal per mile. The Great Northern flyers consume twenty-two and one-eighth pounds of coal per mile, while the New York Central's Empire State Express,



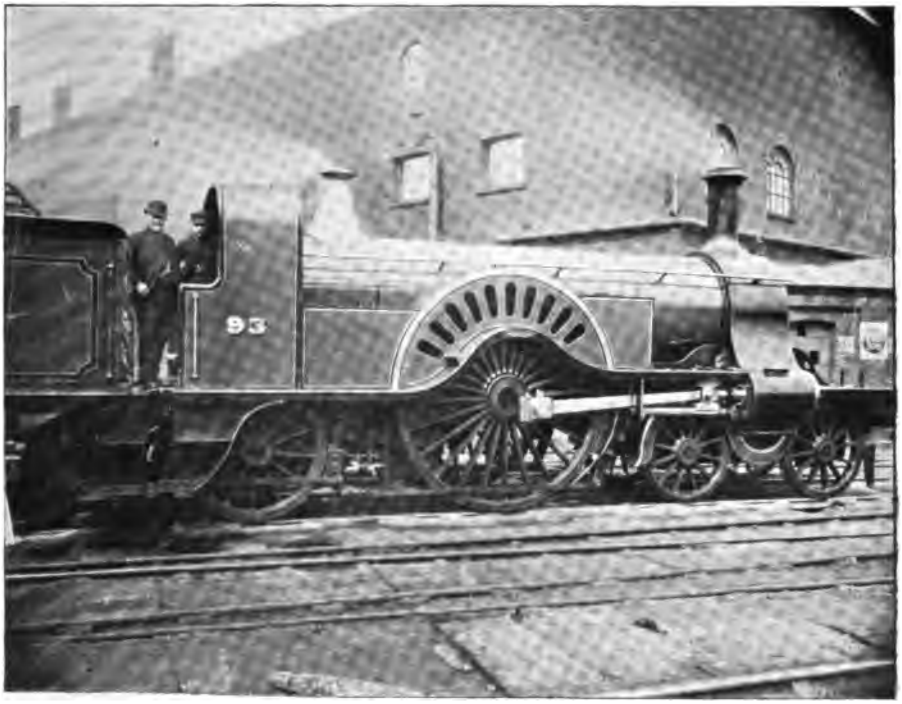
CENTRAL RAILROAD OF NEW JERSEY. VAUCLAIN LOCOMOTIVE USED ON "ROYAL BLUE LINE" TRAIN. HAS RECORD OF A MILE IN THIRTY-SEVEN SECONDS.

according to official figures, consumes forty-five pounds per mile.

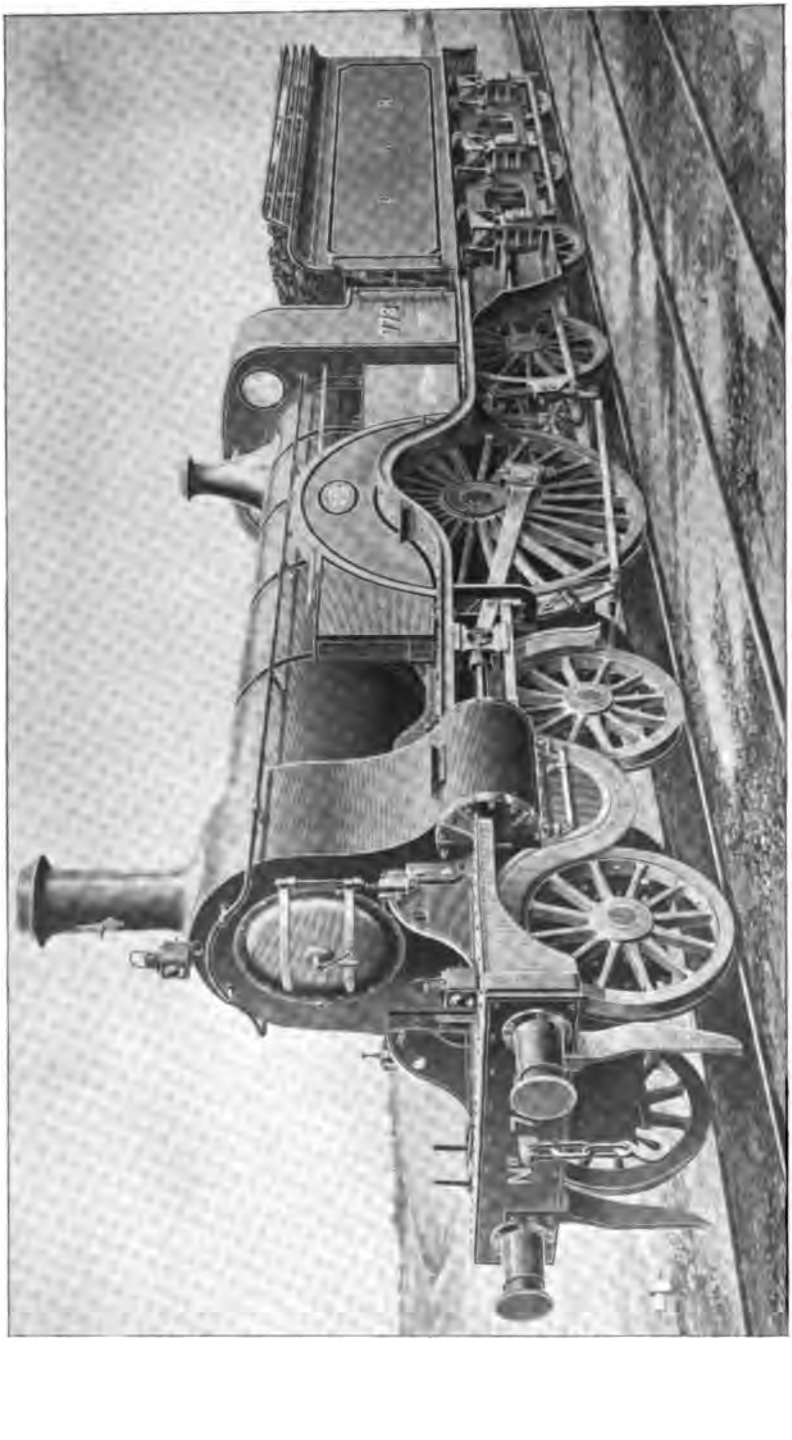
Some exceptionally fast runs have been made on the Great Northern road, when the 105¼-mile course, already alluded to, has been covered in precisely 105 minutes. The first thirty miles out are up-hill. Seven cars, weighing 105 tons, are generally hauled, and as the weight of the locomotive and tender, and passengers, baggage and mails will amount to something like another 105 tons, the total weight of the loaded trains may be safely put at about 210 tons. The performance of a mile a minute by the "Park-Pats" (as the type of engine used is popularly known to the men of the line), with such a load, has never been excelled. The engines are remarkable also for the rapidity with which they get up speed.

The London and Northwestern Railway did some fast running early in the sixties, when a special locomotive was kept at Holyhead for an entire week, waiting to dash off to London with American advices bearing on the seizure of the steamer Trent, of civil war fame. The journey of 264 miles was accomplished in five hours, with only one stop, at Stafford, to change engines, the rate of speed thus being fifty-two miles an hour.

On the Northwestern, the longest run without stops is from Nuneaton to Willesden, a distance of 91½ miles. The run is made by the day express in one hour and fifty-five minutes, being at the rate of something like forty-nine miles an hour; but this is not the fastest. The best time is made between Northampton and Willesden, 60¼ miles being covered in one hour and ten minutes, representing a rate of about 51⅔ miles an hour. The North-



SIDE VIEW OF LOCOMOTIVE DESIGNED BY P. STIRLING, USED ON GREAT NORTHERN RAILWAY FROM LONDON TO GRANTHAM.



BY PERMISSION OF THE ENGINEER, LONDON.

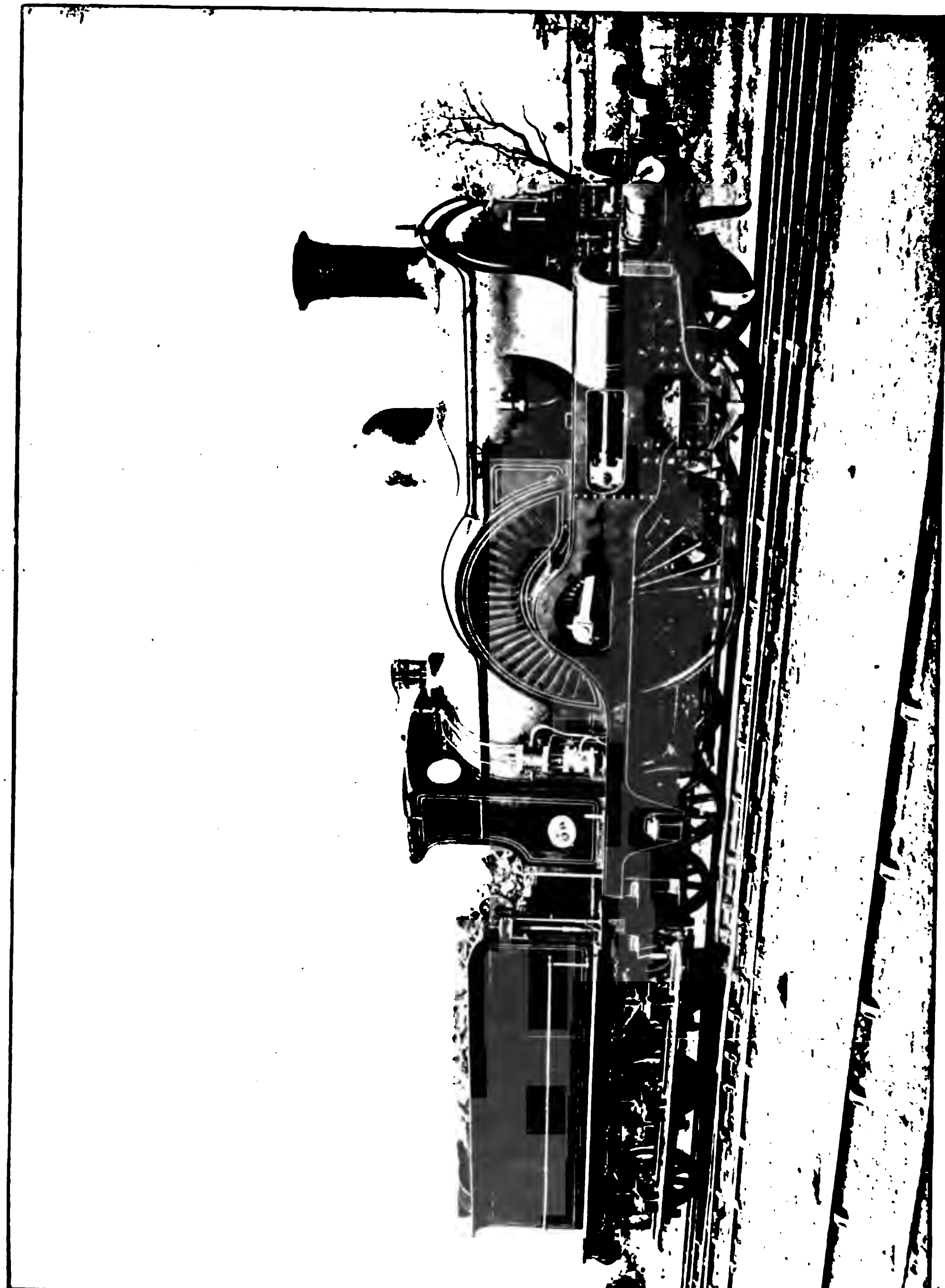
LOCOMOTIVE USED ON GREAT NORTHERN RAILWAY EXPRESS BETWEEN LONDON AND GRANTHAM." WHEEL DIAMETER, 8 FT. 1 IN.—DESIGNED BY P. STIRLING, DONCASTER. 105¼ MILES IN ONE HOUR AND FIFTY-FIVE MINUTES. FASTEST REGULAR SHORT DISTANCE TRAIN IN THE WORLD.

western. it may here be remarked, is the wealthiest road in Great Britain, receiving the greatest subsidy from the government, but, at the same time, being the slowest of the important English lines. The average express rate of speed is only forty-three miles an hour. The London and North-western road for 170 miles out of London has four tracks, so that the New York Central's claim as to being the only four-track railroad in the world

LOCOMOTIVE USED ON NORTH BRITISH RAILROAD SYSTEM ON TRAIN KNOWN AS THE FLYING SCOTCHMAN.

would seem to require some qualification.

The fastest trains in the north of Great Britain are those run in connection with the Great Northern expresses to Edinburgh. The Great Northern Railway's northern terminus is York, about 188 miles from London, and the two-cylinder compound engines of the North British Railway system, in conjunction with the North-Eastern road, take the through trains to the Scottish capital by what is known as the East Coast route. These engines have twenty and twenty-eight inch cylinders, the single pair of drivers being 7½ feet in diameter. The boiler pressure is 175 pounds per square inch. The locomotive and tender, in running trim, weigh eighty-seven tons; nineteen tons come on the drivers. About 4000 gallons of water are carried, and the coal consumption averages 28½ pounds per mile. The engines were built at the company's shops at Gateshead, from designs of Mr. Worsdell, the company's engineer. The engines have the Craven steam sanding jet, and Joy's valve gear. The air pump exhausts into the water tank. In order to get the two large cylinders between the frames, one of them had to be placed a trifle above the other. One cylinder inclines up toward the axle, and the other, back from the front toward it. The two cylinders, both



BY PERMISSION OF LOCOMOTIVE ENGINEERING.

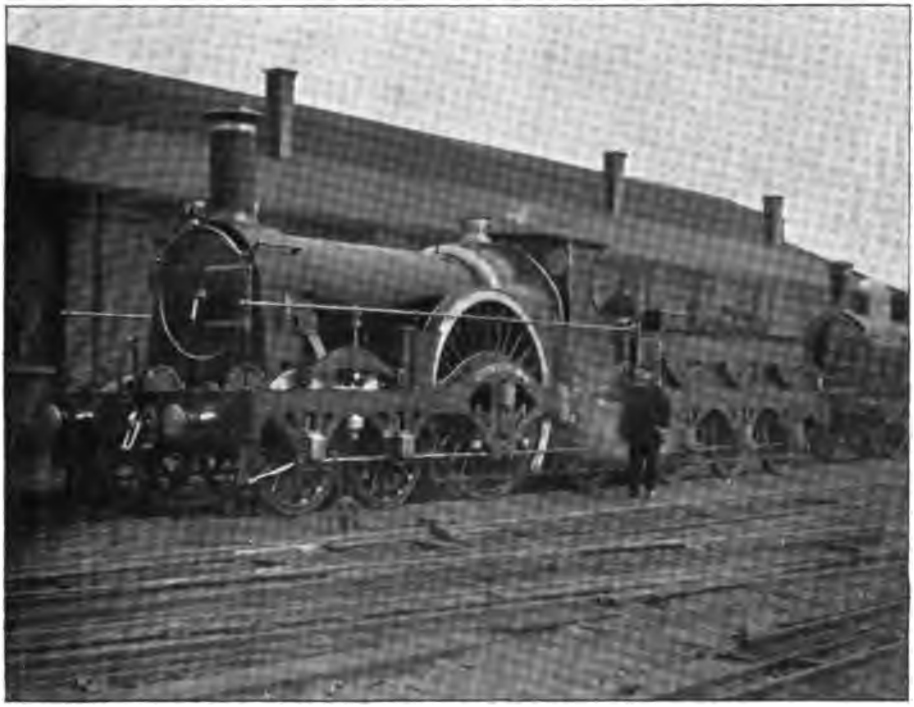
LOCOMOTIVES USED ON CALEDONIAN RAILROAD.

chest covers, and each back cylinder-head, and also the two chests are cast in one piece, so that if any portion gets damaged the whole casting must be thrown aside. The chests each have two small covers, one on the side and one in front. A special type of frame is used to permit the adoption of the side steam chests.

It is stated that on an absolute level one of these locomotives will pull eighteen cars, weighing about 270 tons, at a speed of eighty miles an hour, exerting about 1068 horse-power.

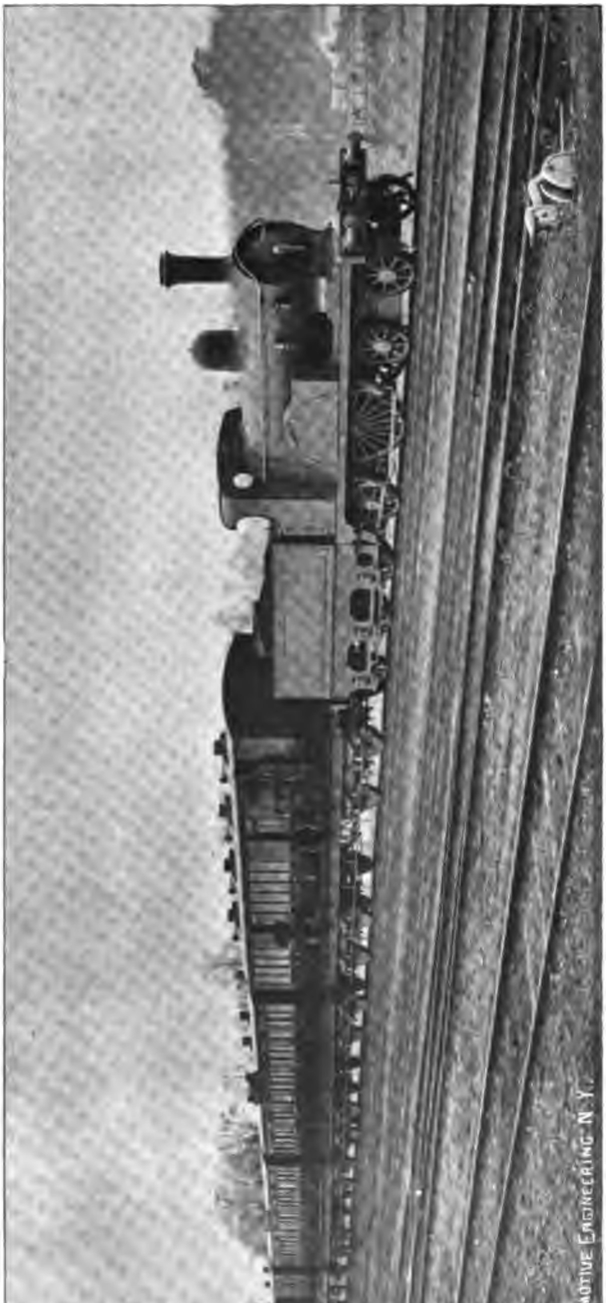
The Caledonian road takes the London and Northwestern express trains north of Carlisle, where the London and Northwestern terminates. The speeds of various fast trains in this section are somewhat above the average, especially that of the London returning post-train, as it keeps in the vicinity of 49½ miles per hour during the 73½ miles between Carlisle and Carstairs. The ultimate eleven miles prior to gaining the Beattock top can scarcely occupy less than nineteen minutes, it being uphill work of one in eighty, and this means an allowance of but seventy-one minutes for the 62½ miles yet to be covered, which represents a rate of, as near as possible, fifty-three miles per hour.

The too often unpunctual London, Brighton and South Coast make their longest run without stopping between Croydon and Eastbourne, 55½ miles, in 1¼ hours, the speed varying from 47½ to 50 miles. The 50½ mile Brighton-London run is covered in one hour by the new 6½ foot coupled locomotives with cylinders 18¼ by 26; weight, ready, 85,000 pounds. For express trains, it takes the place of the old seven foot singles.

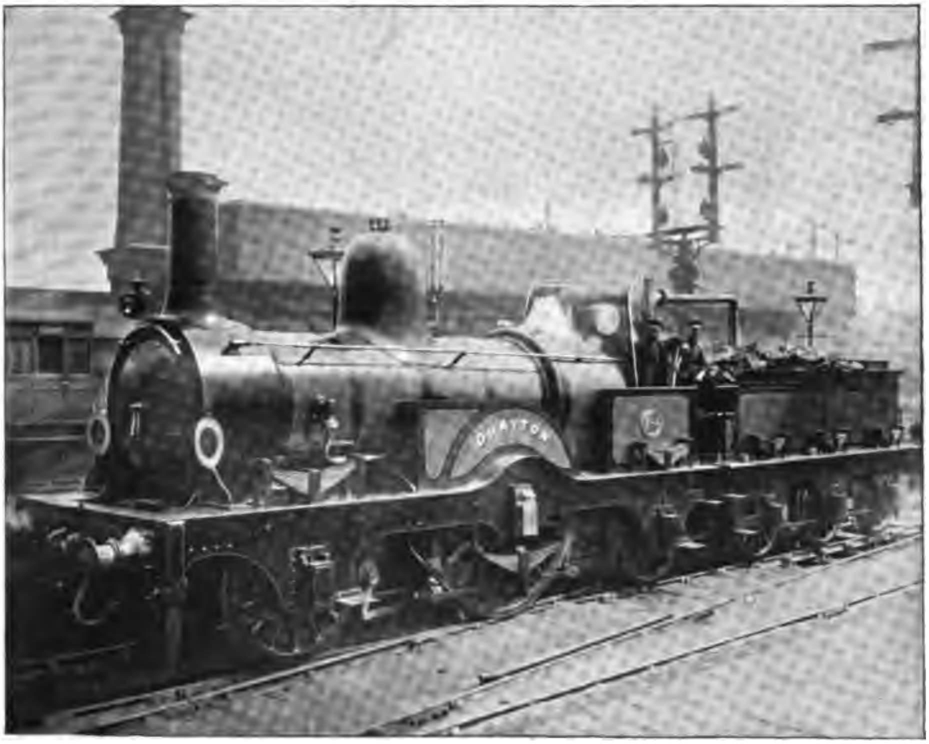


BROAD GAUGE LOCOMOTIVE FORMERLY USED ON GREAT WESTERN RAILWAY.

The Great Western Railway of



A FIRST-CLASS EXPRESS TRAIN—THE DUBLIN BELFAST MAIL.



ENGLAND.—LONDON, BRIGHTON AND SOUTH COAST RAILWAY.—ANOTHER TYPE OF EXPRESS PASSENGER LOCOMOTIVE.

England was the first road in the world to initiate high speeds. The great Brunel held that a speed of 100 miles per hour was feasible with the broad gauge, and during the experiments made by him half a century ago, between London and Bath, this tremendous speed was all but accomplished. For an instance of the notable runs made in those early days of railroading, the reader can refer to The Illustrated London News of August 10, 1844. The English functionaries who are supposed to be near at hand when a babe is born in the royal families, had been hastily advised to proceed from London to Windsor, to be present at the birth of one of the princes. From Paddington (the metropolitan terminus) to Slough—the nearest station in those days to Windsor—the ministerial train covered the 18½ miles in 17¾ minutes. The journey back occupied fifteen minutes and ten seconds. That gives a speed of about seventy-four miles an hour nearly fifty years ago; and allowing for starting and slowing at terminals, and considering the limited brake facilities half a century ago, the running for at least a dozen miles must have been close to ninety miles an hour.

The broad gauge was the maker of high speeds. Had the seven-foot gauge been made compulsory instead of the awkward and too narrow 4 feet 8½ inches, the railroad world would have to-day been the better for it. It is a pitiful example of the survival, not of the fittest, but of the most commercial. To shift freight from narrow to broad gauge, and *vice versa*, caused pernicious results to commerce; and the Great Western Railway gauge, being in a minority, had to succumb.

(*To be continued.*)

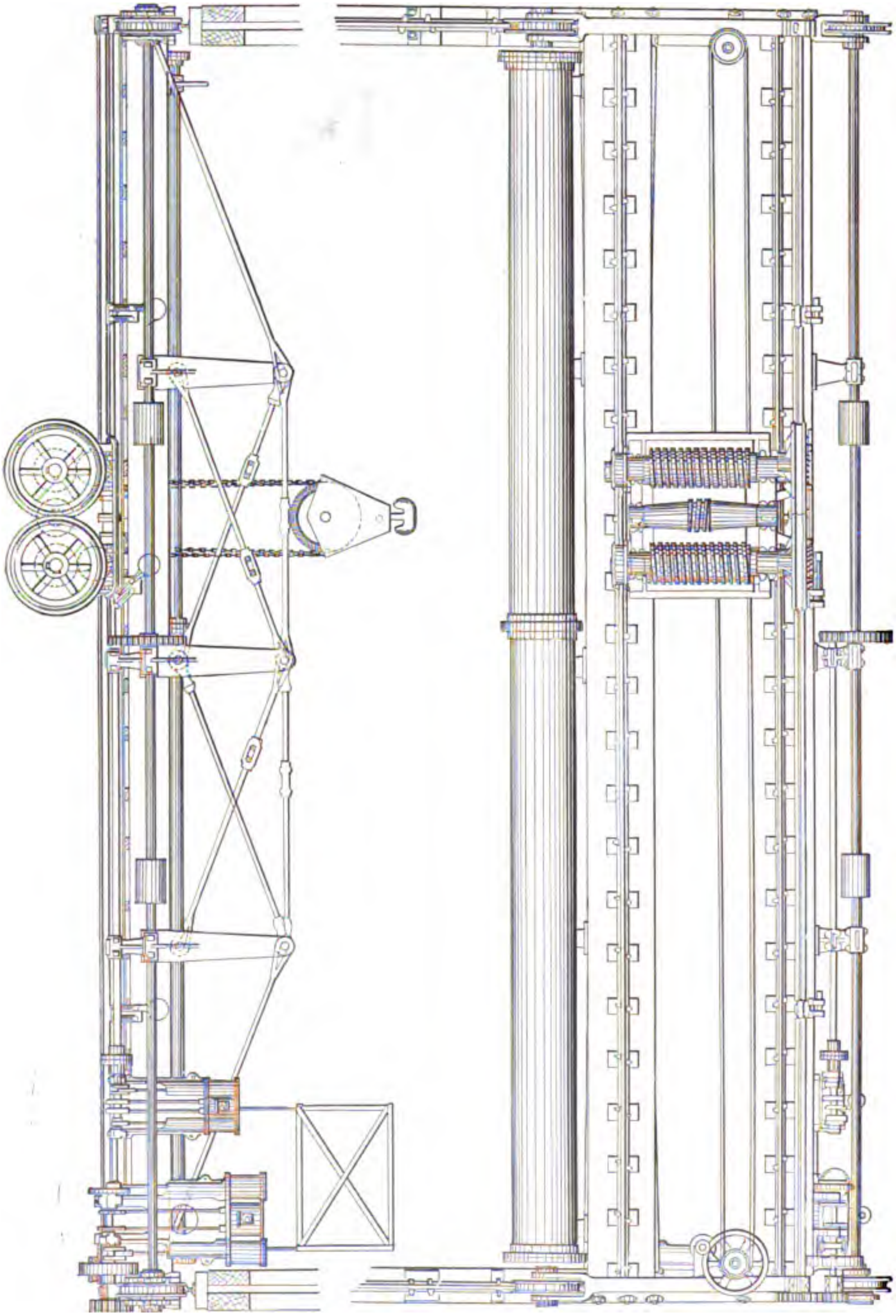
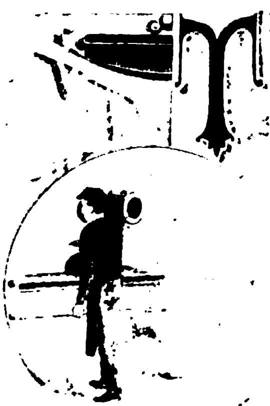


FIG. 1.—ELEVATION AND PLAN VIEW—COMPRESSED AIR OVERHEAD TRAVELING CRANE AT THE WORKS OF THE LANE & BODLEY CO., CINCINNATI, O.

TRAVELING CRANES.

By H. M. Lane, M. E.



THERE are many operators of old and well-established manufacturing plants, the product of which is of considerable weight, as, for instance, machine tools, engines, boilers, and architectural iron-work, who are finding themselves at a disadvantage in competition with operators of less standing, but enjoying the advantages of modern methods of handling.

There is probably no single item which in a mechanical way is further-reaching. The lot upon which the buildings stand and the design of the buildings must be specially adapted for the adoption of the most economical method of handling, which is assumed to be by means of power traveling cranes, and the established plant which admits of their introduction is seldom encountered, and its possessor is indeed fortunate.

Power traveling cranes have long been in general use in England and on the continent, but it is only recently that they have become common in this country, and they are now manufactured as standard appliances by about half a dozen of our machine builders.

The usual spans are from twenty feet to eighty feet, fifty feet perhaps being an average. The capacities vary from two or three tons to 100 tons, speed of hoisting from five feet to forty feet, of trolley travel from twenty-five feet to 100 feet and of bridge travel from fifty inches to 200 inches per minute. The bridge always consists of two trusses, or of plate or box girders, in either case united at each end by trucks which support them on the rails.

The modern high speed of the bridge travel requires a lateral stiffness of the bridge not attained in earlier cranes, and the double box section has been adopted to meet this requirement. Where double box girders or double combination trusses are used, the trolley containing the hoisting gear is placed on top, but plate girders with the trolley running on the lower inside flanges, the girders laterally braced across the top, are very satisfactory, as are plate girders the top and bottom flanges of which are reinforced for lateral stiffness with channels. (See Fig. 3.)

The motive powers employed in an assumed order of desirability are compressed air, electricity, hydraulic, square shaft, flying rope, and steam.

Those of the foregoing methods admitting of reversing variable speed, independent motors on the crane for each motion, viz., hoisting, trolley travel, and bridge travel, are to be preferred, for when the motive power runs in one direction at a uniform speed the numerous clutches and multiplicity of gearing necessary for reversing and changing the speed of each motion become a noisy nuisance.

The triple motor compressed-air crane is believed to be entirely free from disadvantages, unless the necessity for conveying air to the engines on the crane by means of a hose may be considered one. The triple motor electric crane, barring the possible requirements of the services of an expert electrician at a critical time, is equally free from disadvantages.

The hydraulic crane is not handled by an operator in a cage on the traveling bridge, which seems a serious fault. A general sloppiness around pumps, accumulators, plungers, and return tanks

is common, and the necessity for the return of the fluid and its protection from freezing in its passage to and from the plungers is objectionable. The square shafts and flying rope are fast losing favor, and steam is for many ob-

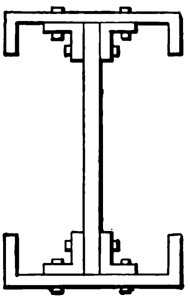


FIG. 2.

vious reasons unsuitable for indoor travelers. The compressed air overhead traveling crane, illustrated herewith, was designed and two of them were built by the Lane & Bodley Company, engine and mill builders, of Cincinnati, O., for their own works, where they have for nearly two years been in successful operation. They are of twenty tons nominal capacity, each about fifty feet span and 400 feet length of the travel, and are of the triple motor type, a pair of simple reversing engines being used for each of the necessary operations, the pair of engines for the bridge and the pair for the trolley travel being each five-inch bore by seven-inch stroke, while the pair for hoisting is seven-inch bore by nine-inch stroke. Air is furnished by a compressor having ten-inch each steam and air cylinders and twelve-inch stroke, which with a boiler pressure of about eighty pounds gives an air pressure when required of somewhat over 100 pounds. The air-compressor is allowed to run continuously without a governor, the speed being very nicely regulated by the resistance of the air in the receiver, which is an old boiler located out of the way in a cellar. From a pipe extending from the receiver along one of the supporting trusses communication is continuously maintained with an auxiliary receiver on each traveler by means of a one-inch hose, the object of the auxiliary receiver being to provide a supply of air near the engines for immediate demands and independent of the hose connection which may thus be of small dimension. The type of bridge truss shown was selected because of the convenience with which it could be built and erected with the existing facilities of the works. The tension members are of square wrought-iron, the posts and end trucks of cast-iron, and the top chords of wood, the great width of which gives incidentally satisfactory

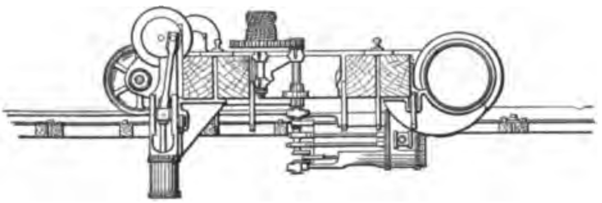


FIG. 3.

lateral stiffness. Some of the advantages thought to be possessed by this type of crane are, briefly, extreme simplicity, absence of all moving parts, excepting those required for a particular motion when that motion is in use ; no danger from fire, leakage, electric shocks, or freezing ; ease of repair by ordinary machinist, variable speeds and reversal without gearing, almost entire absence of noise, and moderate cost. Considerable interest is manifested in these cranes, as they appear to be the first of this type to be put into service.

POWER TRANSMISSION FOR CENTRAL STATIONS.*

By Dr. Louis Bell.

SO far as distribution is concerned, we may divide electrical power transmission into three classes: first, the transmission of single units; second, the transmission of power to a centre of supply from which point it is to be distributed in various ways; third, supplying the power for lights and motors throughout the length of the transmission line. Each of these classes of work imposes conditions on the possible methods of transmission, and requires special consideration. In new plants, hampered in no wise by existing stations, any one of these three cases may exist, perhaps the last two more frequently than the first. Where a single motor is to be employed, the problem is exceedingly straightforward. Where a new centre of distribution is to be organized, some complications are encountered, but not serious ones. Where power is to be scattered along the line, however, conditions arise which are not altogether easy of fulfillment and require a good deal of special care and skillful engineering. In a general investigation of the methods which may be employed, the case stands somewhat as follows, so far as the central station man is concerned:

First, if the distance over which he is to transmit power is moderate, he may use the ordinary direct current generator and motor, displace his engine with the motor and go ahead. But unfortunately, direct current machines of any considerable capacity are practically limited in voltage by the existence of the commutator, an article on which central station men in general waste no love. Dynamos and motors of large size cannot, individually, in the present state of the art, be satisfactorily built for more than about 1200 volts. Machines for greater voltage have very generally broken down in the experimental stage. For very small power units, arc machines might be employed, but for the purpose of the central station man, it is better to move his arc machines directly to the distant point. For voltages much in excess of that mentioned, we are then driven to the use of either direct current machines in series of alternating machines.

Where generators and motors are to be used as a single unit, direct current machines in series may be and are employed quite successfully, but as the voltage desirable on the line rises, the system contains a greater number of units and becomes more complicated and difficult to apply to central station practice. For instance, it is highly desirable for the successful operation of motors in series that they should be, practically, coupled to the same shaft, and should run under similar and uniform conditions, so while there are cases in which the method of coupling in series may be both convenient and cheap, it is in my opinion better general practice to employ alternating currents, after passing the ordinary limitations of direct currents.

Here we encounter a complicated state of affairs, for the central station man who attempts to investigate the subject is immediately surrounded by a cloud of mental dust, through which he sees dimly the outlines of plain alternators, bi-phase, tri-phase and multiphase generators and motors, condensers, Geissler tubes, six-foot fuses, electrified wall-paper and the other properties of a well-equipped modern high voltage electrician. The substance of the matter, however, is something as follows:

We want to use power transmission by alternating currents for two good and separate reasons; first, because we

* Read before the National Electric Light Association.

get rid of the commutator and can therefore use as high voltages as we can safely insulate in the machine; second, because by the use of transformers, we can obtain for the transmission line itself any voltage which we can insulate, and thereby enormously decrease the cost of the copper which must be stowed away as permanent investment in our line.

Multiphase currents, and by this I mean currents having more than one phase, are subject to the same general laws as any other alternating currents. Their most valuable peculiarity lies in the fact that for alternating currents of more than one phase excellent motors can be built which will run at a steady speed, start under heavy load, and in general possess very much the same qualities as a well organized shunt motor of the ordinary kind. Incidentally, certain of the multiphase systems, more especially the three-phase, enjoy the advantage of effecting something of a saving in copper, under favorable circumstances up to twenty-five per cent. from what would be required by a plain alternating current of the same nominal voltage. This saving is merely from the fact that in the three-phase line, the currents do not have their highest value at the same time, so that at any particular instant two of the wires may serve as a sort of multiple return for the third. This advantage would be immediately thrown away, if for the three currents of different phase three separate pairs of wire were employed, as it is thrown away where for two currents of different phase two independent circuits are used.

The fundamental difference between single and multiphase systems, then, is mainly the adaptability of the latter for driving motors, and multiphase are better than single phase motors principally in their ability to start under load, and somewhat larger output for the same weight.

Wherever, then, single motors are to be driven for operating, we will say an electric light station, it is largely a matter of convenience whether we employ single or multiphase motors. If the ormer can be conveniently started, they are fully competent to take care of the work, except in one special case which I will mention presently. The multiphase motors, whether synchronous or otherwise, start very freely, and may or may not be economical in cost of copper, according to the arrangements of the circuits.

A single case in which multiphase transmission becomes of great importance when the object is to work an existing central station is in that case where railway circuits are to be supplied. A railway machine is subject to so great and violent variations of load, that if it were driven by an ordinary synchronous alternating motor, the latter would run great risk of being pulled out of phase by a sudden short circuit, when it would stop and stay stopped until deliberately started up again. The multiphase motor can also be pulled out of phase, but not quite so easily, and it can be more readily started. We can, however, where railway currents are necessary, do much better than to drive the dynamos directly by motors of any kind. We can for this use start with the multiphase current, and through the medium of a single machine, scarcely more complicated than an ordinary railway dynamo, transmute this multiphase current into a direct 500 volt current of the ordinary sort. This very valuable result has been brought about through the ingenuity of C. S. Bradley, who invented the device half a dozen years ago. It has remained dormant, principally because there has been no special call for power transmission of any kind until recently, but to its thorough practicability I can personally testify, as a 100 kilowatt tri-phase direct current transformer, which I recently tested, operated in the manner described, showed an efficiency of over ninety-five per cent. at full load, stood sudden variations from no output up to 100 kilowatts and back again without even a wink at the brushes, and bore up under heavy overload without difficulty. Whenever it is desirable to operate railway circuits by power derived from a distant source, these machines fulfill all practical requirements, and I believe

are destined to come into very extensive use, and play an important part in the development of very long electric railroads.

To sum up this point, where single motors are to be employed for driving other electrical machinery, either synchronous, alternating or multiphase motors can be successfully employed. Where railway dynamos form a part of the load, a particularly good result can be obtained by using for this particular portion of the work the multiphase direct current transformers.

So much for the operation of existing plants by electrical transmission of power, where it is merely intended to substitute a motor or motors for an engine.

Now, take up the case where a centre of distribution is to be fed, consisting it may be in part of an existing station and in part either of extensions and new circuits from this plant or subsidiary centres of distribution having other districts of the same town. Here the problem becomes more complicated and it is almost impossible to lay down any general procedure. Each case is best handled by itself. We can, however, enunciate certain principles which will aid in the discussion of any definite case.

First, we can feed all existing railway circuits and extensions very effectively and economically by use of the tri-phase direct current transformer just described.

Second, we can handle all direct current incandescent systems, whether two or three wire, by means of the same type of apparatus, the tri-phase direct current transformer.

Third, we can successfully operate any existing alternating incandescent circuit or any extensions thereof by feeding alternating current from the distant point directly into them through banks of transformers.

Fourth, if any new centres of distribution are to be made with circuits independent of those already in existence, we can operate these circuits very effectively for both lighting and motor service, if both be necessary, by employing multiphase apparatus; and right here let me say that there is one widely spread error which I desire most emphatically to contradict.

It has been asserted that incandescent lighting cannot be successfully done on multiphase systems, especially tri-phase, since this system happens to have been most talked about. This statement is absolutely false, to my own personal experimental knowledge. Lamps can be as successfully operated on systems of two, three or more phases as on an ordinary single phase circuit, provided equal pains be taken with the distribution of copper in the lines and the regulation of the voltage at the dynamos. If these conditions are observed, a two-phase circuit with separate wires acts substantially as if it were fed from two ordinary alternating dynamos. A tri-phase circuit gives a similar result, and if more phases were concerned, the same would be true. If the condition of constant voltage at the centre of distribution be fulfilled, as it can be and must be for successful operation on any system whatever, two and three phase incandescent lighting systems can and do work admirably. Furthermore, if we combine circuits, for example, if we use but three wires instead of six for the three-phase system, there is no exact equality of balance required between the lamps placed in different connections across these circuits. On the three-phase system we would place between each possible pair of the three wires this arrangement, gaining in copper wire enough to compensate for the slight inconvenience in connecting three sets of lamps instead of one or two. Branches can be run from any two wires of the tri-phase arrangement, and lights placed on them will act exactly as if they were placed on any ordinary alternating circuit. With such an arrangement you should be able to throw off all the lights on one side of the circuit, without producing any noticeable variation in the lights of the other two branches; no more variation, for example, than you would get, if on a given set of secondary mains from a common transformer, you were to turn off or

turn on one-third of the total number of lights. If any man comes to me and says that a three-phase system will not run lamps successfully unless there is careful balance between the lights on different sides of the circuit, I have in that statement sufficient evidence to convict him either of ignorance of the principles of wiring and dynamo regulation or of willful misrepresentation of the facts. I lay stress upon this matter of incandescent lighting in defense of multiphase systems, because it is the one upon which they have been most often misrepresented, chiefly through foreign experiments, which I do not hesitate to denounce as clumsily conducted.

In taking up the condition I have just mentioned—that of new centres of distribution—may briefly refer to the properties of multiphase motors, which have been the subject of all sorts of curious misstatements. A multiphase motor, I do not care whether it has two or more phases, should if properly built have very nearly the properties of a good shunt motor, and not far from the same efficiency. Incidentally, it has the advantage of having no commutator and no necessity for any moving contacts. It starts under two, three or more times the running torque, just as a shunt motor does, and by virtue, if the torque is extreme, of a heavy starting current just as a shunt motor would. It comes rapidly up to a nearly fixed speed, and remains nearly at that speed under variations of load. If overloaded it stops, like any other motor. In addition, it has one great merit that shunt motors do not have, that of running at nearly constant speed independent both of load and moderate variations in voltage. It is on the whole less thin-skinned than a shunt motor. I have experimented with a considerable number of multiphase motors of the induction type, to which I here especially refer, and although I have seen some terribly severe tests in the way of overload, I never yet saw any symptoms of a burn-out. The efficiency of these machines should be and is at least within one or two per cent. of ordinary shunt motors. There has been much discussion as to the relative merits of two and three-phase induction motors. In general the more phases, the smoother action of the machines in various respects. I have never yet seen a two-phase motor any better than a three-phase motor. I should want a pretty careful series of tests to convince me that I had seen one as good. The difference between them, with proper design, ought not to be very great, though the three-phase has the advantage in cost of wire. There are two important points in which multiphase motors have been misrepresented, which I shall mention.

First, it has been said of them that they take an enormous current when running light, and second, that they introduce a very large and most objectionable lag in the circuit, so that the apparent current on the line is much greater than the energy current. Such facts have doubtless been observed. Broadly speaking, they have been due to faulty design. A multiphase motor will always take a somewhat larger current when running idle than the corresponding direct current motor, but it takes very little more energy, as the phenomenon of lag then becomes noticeable, so that of the apparent current running light only a portion represents energy. It is a perfectly simple matter to cut down the current required by a multiphase motor running idle to twenty or twenty-five per cent. of the full load current, still retaining a motor excellent in its other properties. As motors where power is sold by meter are usually cut off when not needed, the whole question of this idle current sinks into insignificance. The same is true of the alleged lagging current. If a multiphase motor (I speak with certainty at least regarding the three-phase) of ten or fifteen horse-power should show at full load more than ten or twelve per cent. of lagging current, I should consider it to be badly designed, so that these two questions of so-called idle current and lagging current as disturbing factors in a multiphase line can be and are reduced by proper care in designing to comparatively insignificant

quantities. It has been very ingeniously suggested to give them a further shove down into oblivion by means of condensers, but it is a commercial rather than an electrical question as to whether leakage current and lag had better be thrown quite into the abyss by the added complexity of condensers or left hanging on the ragged edge without them.

In case, then, of working a central station from a distant water-power where necessity for extensions or new centres of distribution exists, we have plenty of methods available: Tri-phase direct current transformers for railway and direct current lighting service, alternators to feed into the existing mains or to supply extensions for them and for new centres where light alone is to be employed, ordinary alternating currents, or where both light and power are necessary, multiphase apparatus which, as I have shown, is entirely applicable for such a mixed system.

I may add that there is a possibility that we may have before long practicable motors to run on an ordinary alternating circuit constructed after such methods as were suggested by Prof. Thomson a few years ago. In very small sizes they are already practicable. Brown, abroad, has been making a desperate effort to exploit these very methods on his own responsibility and has obtained motors which run successfully but as yet do not start well under load. From what I can learn of them, I doubt very much if they are any improvement on the motors of the same type shown by Prof. Thomson at the Paris Exhibition or on Mr. Tesla's motors for running on a two-wire circuit.

Whatever the methods which may be employed, several serious questions must be confronted when one attempts to transmit power for supplying central station or any other apparatus. One of these which presents itself immediately is whether or not in an alternating transmission it is advisable to use step-up and step-down transformers. The principal determining factor in this is cost. The higher voltage we can supply direct from the machine without increasing its cost considerably, the cheaper we can make the installation. Unfortunately in building dynamos, the armature coils have to be insulated, and where the voltage is very high, the insulation is correspondingly thick, so that with a given amount of material, we must in building a high voltage machine take up with insulation the space which would otherwise be available for copper. The result is that a dynamo wound for 4000 or 5000 volts is intrinsically more expensive, unless the size be very large, than a machine wound for 1000 or 2000 volts, besides being considerably less reliable. Machines of such voltages as these have been built in this country and abroad and some of them have given very fair results, but they are expensive to manufacture, at whatever prices they may have been sold in individual instances, and it is my personal opinion that where it is necessary on the score of economy to raise the voltage as high as 4000 or 5000 volts, it is better and cheaper, unless the units be very large, to use step-up transformers and carry the voltage up to 10,000. Assuming 2000 or 3000 volts as the available potential obtained from the machine direct and then estimating the cost of a given installation, first using these machines and second using low voltage machines with step-up transformers, we find that at prices ordinarily charged for apparatus and copper, the two methods become of equal cost at a distance of somewhere about seven or eight miles. Above these distances, the step-up transformers cheapen the plant; below it, they increase the expense. We can draw the line at no specified given distance for the general case, but can very easily for any specific case.

The amount of drop advisable in these long distance lines will depend of course principally upon the relative prices for copper and the apparatus necessary. If copper be relatively cheap, it pays to employ a good deal of it. If apparatus is relatively cheap, it is better to use larger generators and allow more drop on the line ; fifteen to twenty per cent. will hit the large majority of cases

on the score of economy and convenience. It should be remembered, however, that for such drops as these good regulation is most essential, but good enough is available with direct, alternating or multiphase machines, to make these drops thoroughly practicable. The approximate figures I have just given on the limitations of the step-up transformer and on drop are the result of the investigation of a large number of concrete cases which I have had occasion recently to examine in detail, and for a number of which the apparatus is now in process of manufacture. I therefore feel personally convinced of their practicability, both theoretically and otherwise.

But for the central station man who desires to decrease his operating expenses by the employment of electrical transmission the court of last resort is the balance sheet and the fundamental question is, "Agreed that it is practicable, will it pay?" I can give no general answer to this question, for each problem necessarily must be considered by itself. It is possible to formulate equations which will connect all the variable factors of cost and annual charges, so as to enable one to derive from them an answer to this all important question. But the character of such formulæ is necessarily so complex and involves so many quantities that it is generally easier to take a short cut to the result by making a few approximate estimates. I have, however, looked into the profit and loss probabilities of a large number of plants of all descriptions and in a general way one can say that power transmission to a central station will, unless the cost of developing the water power be very great, almost universally pay at distances of ten or twelve miles or less. It will frequently pay up to twenty or twenty-five miles; now and then, under extraordinary conditions (very expensive coal and very cheap water power), up to forty or possibly even fifty miles. In using alternating currents at these long distances one naturally fears the effects of inductance in the lines and of static capacity. In very long lines, operated at high frequency, these difficulties may rise to formidable magnitudes. Knowing the dimensions of the line, the frequency and the currents, it is, however, possible to calculate the effects of these distributing elements with great accuracy. From these calculations I feel safe in saying that within the distances mentioned inductance and static capacity constitute no serious obstacles to success, if the frequency employed be moderate; such, in other words, as one would be led to select in considering the operation of motors alone. Large generators are as readily and nearly as cheaply built for frequency of fifty or sixty as for higher ones; sometimes more easily under these circumstances. I think cases would be rare where transmissions, the advisability of which would be dictated by commercial consideration, would encounter serious difficulty from inductance and capacity. I have never personally investigated a proposed transmission of over fifty miles that gave any promise whatever of financial success, but the time may come when such a case will appear, and if it does, the work can be done successfully so far as the electrical part of the matter is concerned. I think the greatest difficulty in surmounting long distances is the difficulty of keeping a long line in proper repair.

Throughout this discussion I have taken the position that no one method of procedure is applicable to all cases. Personally I am decidedly eclectic in my taste, believing that it is better to put in for each individual case such apparatus as on the whole proves to be cheapest and best rather than to advocate, on any fine drawn theories, methods which might be applied to the perfectly general case of transmission of power. It is the concrete rather than the abstract that we have to consider when proposing apparatus on which the success of large commercial affairs depends.

MODERN GAS AND OIL ENGINES.

By Albert Spies, Mem. Am. Soc. Mech. Eng.

Third Paper.

SOME uses to which gas engines are especially adapted have been mentioned in a previous article; one of these is the driving of electric light machinery, especially the dynamos of isolated lighting plants, where steam engines with the necessarily attendant boiler equipment are often undesirable. Ease of management and simplicity of power installation in such plants are frequently of the utmost importance and, coupled with the intermittent character of the service required, make the gas engine a prime mover of special acceptability. One of the several later types of gas engine which appear to have found much favor for such electric light service is the White & Middleton engine, built by the White & Middleton Gas Engine Company of Baltimore, Md., and illustrated in Figs. 36 and 37, the latter representing a sectional plan. This engine is of the prevailing two-cycle or so-called Otto type to which repeated reference has already been made in connection with many of the engines described in the previous articles.

The piston is of the trunk pattern and is connected to the crank direct by the wrist-pin and connecting rod without an intervening cross-head. The gas and air are mixed in the chamber *a*, and the mixture is drawn through the valve *b* into the engine cylinder during the out-stroke of the piston. During the return stroke the mixture is compressed to about one-fourth its original volume, and, at the beginning of the second out-stroke, it is ignited by uncovering the inlet to an ignition tube. The ignition, or explosion, of the charge drives the piston forward. At the end of this working stroke, as it may be called, the piston uncovers the exhaust port *f* and the larger part of the products of combustion escapes. The portion still remaining in the cylinder, except that filling the compression or combustion chamber on the left-hand end, is expelled, during the following return stroke, through the valves *c* and *d*. This completes one working cycle, and the engine is then ready to take in a new charge of gas and air and go through the same series of operations.

The valves, it will be noticed, are all of the poppet type. The valve *c* is worked by the lever *g* pivoted at *h*. This lever receives its motion from the rod *i* and the latter, in turn, is operated by the slide *k*. A cam is placed on the crank-shaft at *l* and works with a smaller cam which imparts motion to *k*. This smaller cam is under the control of a centrifugal governor and a spring, being thrown out of gear with the larger cam whenever the speed of the engine exceeds the normal rate, and thus failing to open the admission valve *c* and the gas supply valve until the engine has again come down to its proper speed. Ordinarily, when the engine runs under a full load, these valves, of course, open at every other stroke. The valve *c* always opens slightly in advance of the gas supply valve, the latter being arranged in the casing shown at the side of the cylinder in the perspective view, Fig 1. In Fig. 2 it is not shown. A small valve is fitted to the opening *n*, and is opened and closed by hand for the purpose of relieving the air pressure in the cylinder on starting

the engine. It will be observed that, unlike many other gas engines, the one here shown has no gear wheel combination for reducing the speed for the valve gear, the necessary reduction being effected by an ingenious arrangement in the slide *k*. The governor also is quite to be employed, however, the gas supply valve on the side of the cylinder is replaced by a small pump worked also by the rod *i*. No outside carburetor is employed, but the pump discharges at every other stroke of the engine piston, or less frequently as de-

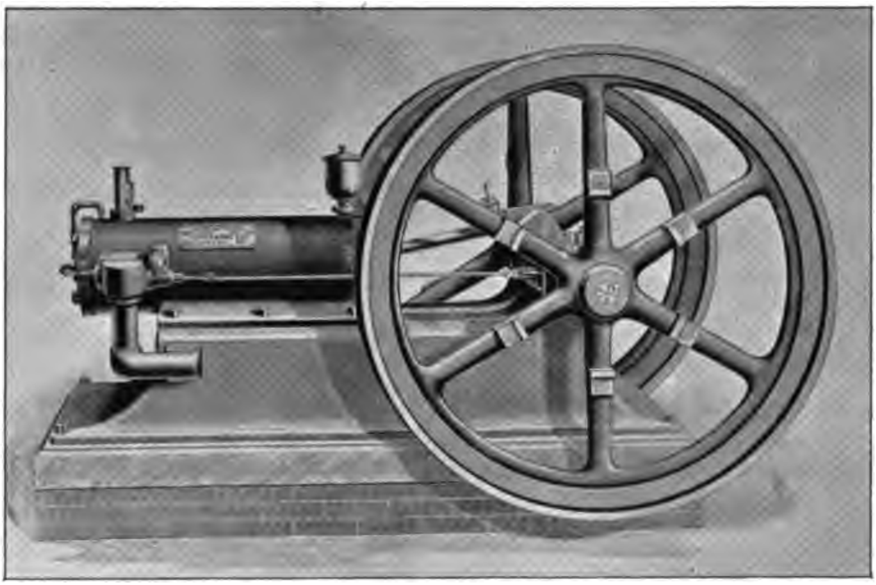


FIG. 36.—ENGINE BUILT BY THE WHITE & MIDDLETON GAS ENGINE CO., BALTIMORE, MD.

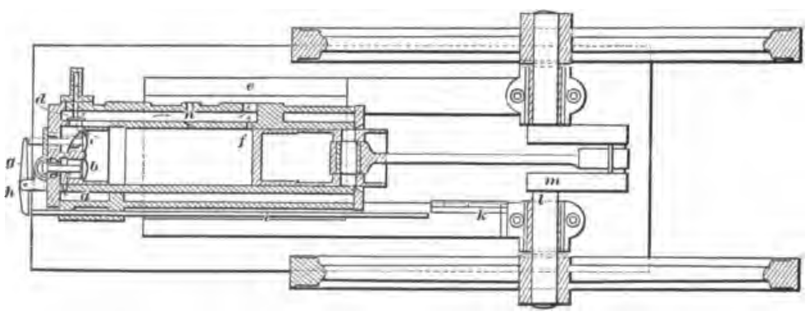


FIG. 37.—SECTIONAL PLAN OF WHITE & MIDDLETON ENGINE.

inconspicuous, and the whole engine is very simple in appearance, the number of working parts having been reduced to a minimum. termined by the position of the governor, a suitable proportion of gasoline into the chamber *a* where it is taken up and carried along by the air into the cylinder through the self-acting valve *b*. The engine is built in sizes of from two to thirty-two indicated horse-power,

The engine, like many of those already described, is adapted to use gasoline as well as gas. Where gasoline is

though arrangements are being completed to turn out larger sizes for which demands have been made.

The gas consumption of the engine is said to be remarkably small, test figures being claimed to have shown a consumption of nineteen cubic feet per brake horse-power per hour, in an engine developing actually 5.98, or in round numbers, six horse-power.

The combustion or power chamber is formed partly in a separate hood, as shown in the vertical section Fig. 39, and communicates at one side of the latter with the supply valve port. The forward end of the power cylinder opens into the crank casing which forms a compression supply chamber, the piston being the compressor. In this chamber work the connecting rod and crank,

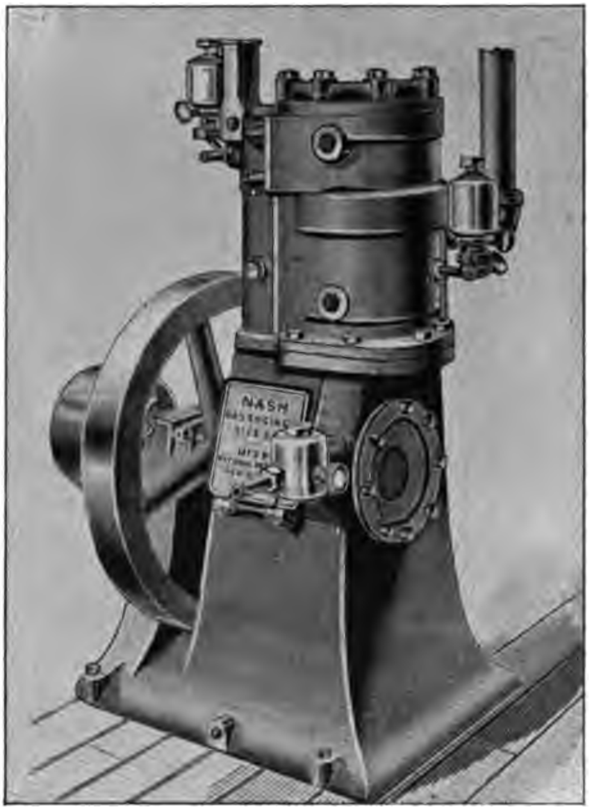


FIG. 38.—THE NASH ENGINE, BUILT BY THE NATIONAL METER CO., NEW YORK.

Another one of the later designs of American gas engines, known as the Nash engine, and built by the National Meter Company, New York city, is shown in perspective in Fig. 38. In this engine there is one explosion of a gas and air charge at every revolution instead of at every second revolution, and the engine is thus practically single-acting.

and into it the combustible mixture of gas and air is drawn during the upward stroke of the piston through the mixing valve, shown in Fig. 40, which is placed externally as represented in Fig. 41. This valve automatically regulates the relative supply of gas and air to the cylinder. Air enters through the opening at the bottom, while the flow of gas is regulated by the valve *f*.

In the interior are two valve ports of unequal area controlled by the double-seated valve *i* which regulates the flow of gas through the smaller port, and the flow of air through the larger one. It is evident that the relative quantities of air and gas drawn in by the upward movement of the piston will be in accordance with the size of the air and gas openings. The valve *i* is made of sufficient weight to greatly overbalance the gas pressure so that any slight variations in the latter will not materially effect the proportions of the parts of the mixture.

From the supply reservoir the mixture passes upward through a passage clearly shown in Fig. 39. Its admission to the combustion chamber above the piston is controlled by a poppet valve having an ample seat. The quantity of mixture admitted at each stroke is controlled by the valve *k*, operated by the governor. After ignition and expansion, the products of combustion escape through the circumferentially arranged exhaust openings in the cylinder walls, which are shown in both the sectional views and which are uncovered by the piston at the end of its down-stroke.

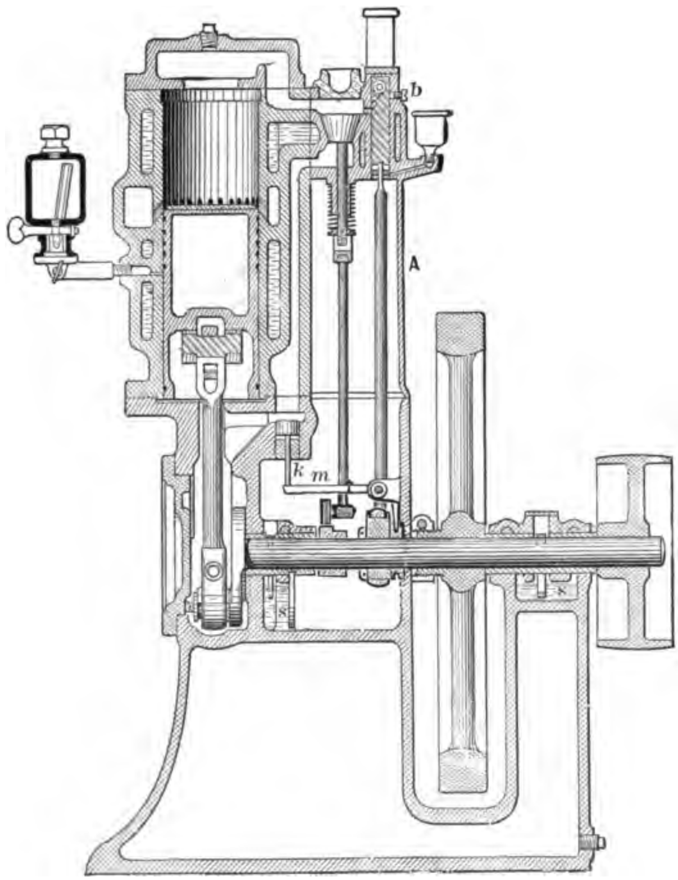


FIG. 39.—VERTICAL SECTION OF NASH ENGINE.

The igniter *b*, Fig. 39, and shown enlarged in Fig. 42, is based upon a new principle. The igniting jet of combustible mixture is caused to rotate in the circular chamber *r*, into which it enters through a passage tangentially placed. This forms a vortex of flame, which is

positive in its action and simple. The valve B itself is made of steel, and is hardened and ground to size. It moves in a reamed hole in the case, being so loosely fitted as to drop of its own

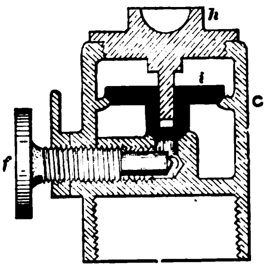


FIG. 40.—NASH MIXING VALVE.

weight, and yet making a gas-tight joint. Since the valve is pefectly balanced as to gas pressure it moves without friction, and therefore requires a very small quantity of oil—just sufficient to prevent it becoming dry. The valve is made long, and the lower part has a bearing in that part of the case kept cool by a water jacket. As oil is only applied to the lower end, very little can work up to the hot end where the igniter is heated ; hence the formation of gummy oil is prevented, and the valve seldom needs cleaning. In actual use it has been found that the case and upper end of the valve never come into metallic contact, as, on account of the looseness of fit at that point, a scale of hard carbon is formed over the surface of each, which protects them from abrasion. The valve is positively operated by an eccentric on the shaft.

As already stated, the engine ignites each charge at each revolution, and the amount of the charge is controlled at each stroke by the governor, so that the regulation is as close as for a steam engine. An examination of a card taken from this engine shows a remarkable resemblance to the card of a steam engine. The pressure at the beginning of the stroke is moderate, and the line of the expansion is well sustained throughout the entire stroke. The flywheel is stationed between two bearings formed in the single base casting ; hence the alignment of the shaft is always true. The working parts are enclosed and protected from dust, and at the same time they are readily accessible by hinged covers.

The engine is made in sizes of from one-third actual horse-power up to four horse-power, and, like all others of its class, is adapted to a wide variety of work. A special engine and pump combination, put on the market by the makers, has met with much favor and is widely used. Gasoline can be used with the engine as well as gas, but in that case, of course, some kind of carburetting device must be employed which forms an independent adjunct.

The Backus engine, made by the Backus Water Mfg. Company, of Newark, N. J., is shown in Figs. 43 and

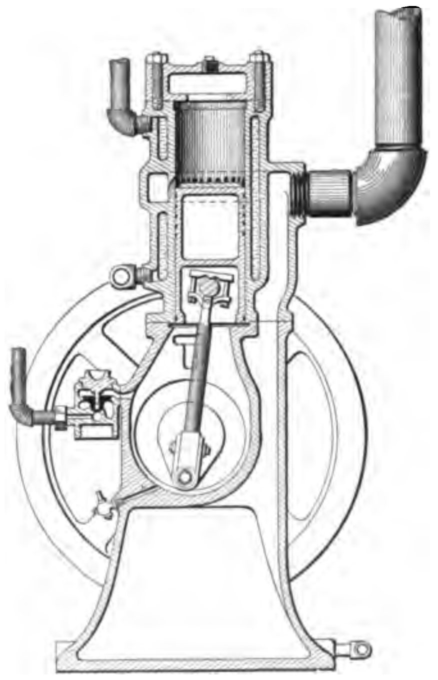


FIG. 41.—VERTICAL SECTION OF NASH ENGINE.

44. It is a vertical engine, made for small powers, and, like several already described, works according to the Otto cycle, there being one explosion in every two revolutions. Fig. 44, which

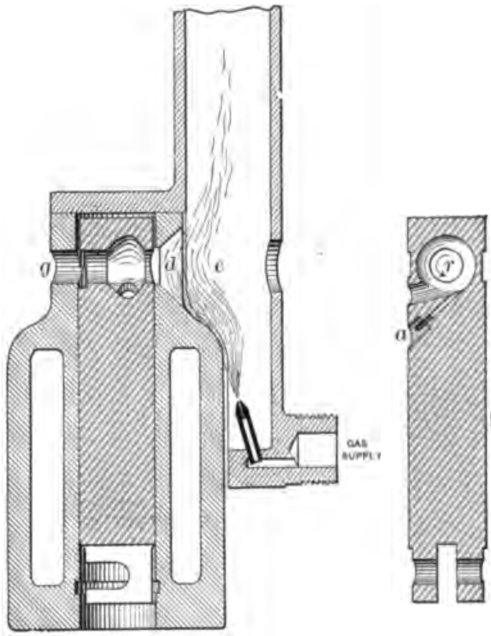


FIG. 42.—IGNITER OF NASH ENGINE.

represents a vertical section of the cylinder and valve mechanism, will help to clearly explain the functions of the several parts. The gas, coming through a special gas regulating valve, shown at the left in Fig. 43, enters at *a*, and, mixing with air, enters the engine cylinder through the admission valve *b*. This valve is ordinarily held down on its seat by a helical spring, not shown in the illustration, but lifts during the upward suction stroke of the piston, opening communication between *a* and the cylinder. Above the valve *b* is the exhaust valve *d*, which also is held to its seat by a helical spring, except when opened by the action of the exhaust valve rod which is operated by a gear wheel running at half the speed of the crank shaft. The exhaust pipe is indicated by the dotted circle above the valve *d*.

When the piston makes its first upstroke, the valve *b* opens and the explosive charge is drawn into the cylinder, the exhaust valve *d* being closed. On the following down-stroke compression takes place, both valves *b* and *d* being closed. At the end of this stroke the charge is in such a state of compression that it becomes ignited through that portion of it which has entered the incandescent ignition tube *c*. The piston is then forced up, doing useful work, and during the next down-stroke or exhaust stroke, the valve *d* is open and the waste gases escape. The engine, after this, is again ready to recommence the same cycle.

The governor, which is of the centrifugal type, is arranged in the belt pulley shown at the upper left-hand corner of Fig. 43. As the revolving weights of the governor move outward under the influence of centrifugal force they move the upper end of a centrally pivoted lever, shown in the perspective view. The lower end of this lever is attached to the gas valve, which is thus opened or closed more or less, depending upon the engine speed and the corresponding position of the governor weights. At the lower end of the lever there is also a knurled collar, by turning which the connection between

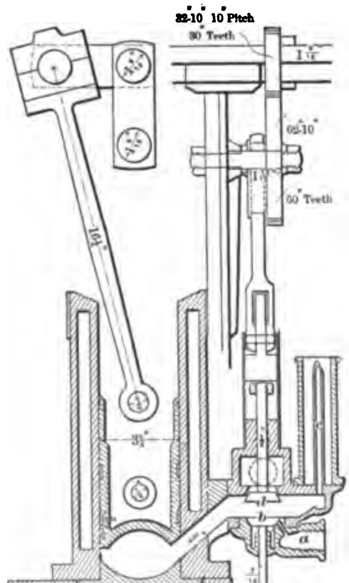


FIG 44.—VERTICAL SECTION OF THE BACKUS ENGINE.

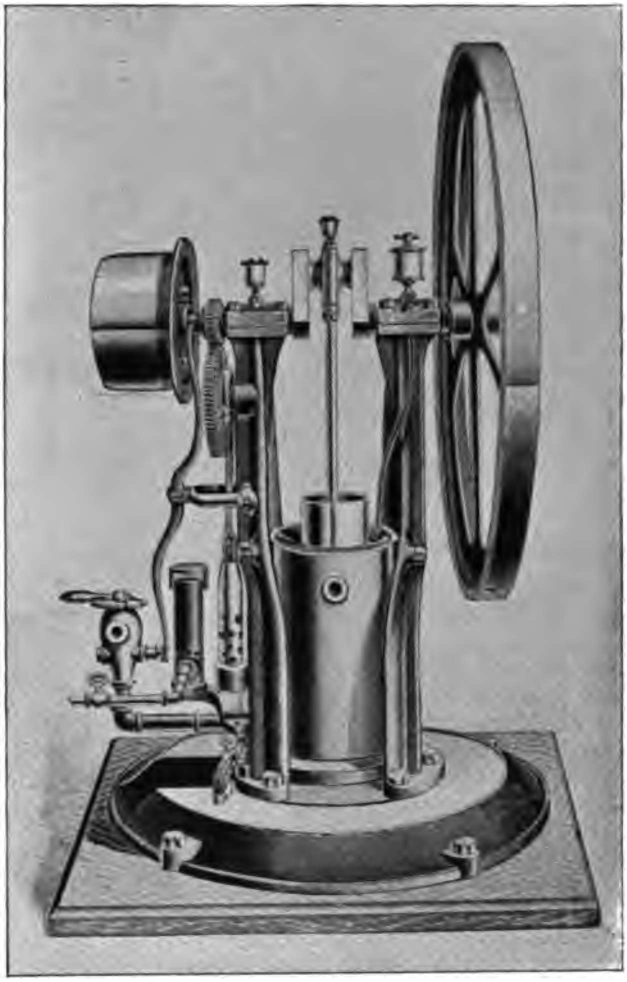


FIG. 43.—THE BACKUS ENGINE, BUILT BY THE BACKUS MANUFACTURING CO., NEWARK, N. J.

the lever and valve can be either shortened or lengthened, and the speed of the engine can thus be changed while the engine is in motion. The engine cylinder is provided with the customary water jacket to prevent overheating. The sizes of the engine range from one-half to three horse-power.

(*To be continued.*)

MACHINERY HALL, WORLD'S COLUMBIAN EXPOSITION.

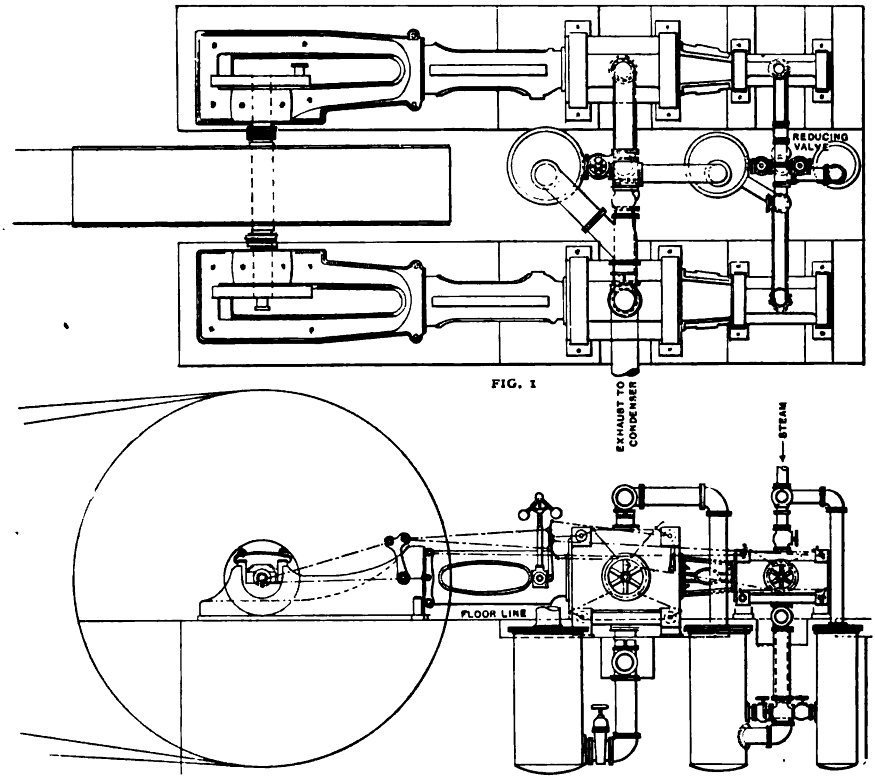
STEAM ENGINES AT THE WORLD'S FAIR.—I.

By Geo. L. Clark.

OF all the great structures at the World's Columbian Exposition at Chicago, the Administration Building, while not the largest, is one of the most beautiful, if not the gem of the Exposition palaces. Machinery Hall, however, has been pronounced second only to this in the magnificence of its appearance. It measures 846 by 492 feet, and, with the Machinery Annex and Power House, cost about $1,250,000. These several structures together cover an area of nearly eighteen acres. The main machinery hall is spanned by three arched trusses, and the interior presents much of the appearance of three great railroad train houses. In each of the long naves is an elevated traveling crane, running from end to end of the building for the purpose of moving machinery. During the time of the Exposition it is intended to put platforms on these, so that visitors may be carried throughout the exhibition space and view all the machinery.

That with such extensive provisions for the exhibit of machinery the latter will form a most important feature of the Exposition seems almost needless to say, and that steam engines will be of the first prominence in this line of exhibits will be equally well appreciated. Interest will undoubtedly be centred in the large Corliss engine, one of magnificent proportions, built by the E. P. Allis Company, of Milwaukee, Wis., and suggestive at once of comparison with the famed Corliss engine used in Machinery Hall at the Philadelphia Centennial Exhibition in 1876, which was built by George H. Corliss. The illustration of that engine, shown on another page, will give the reader some idea of the great dissimilarity of the two. This Corliss engine, at the time one of the finest examples of its type ever constructed, had a pair of forty-inch cylinders, of ten-foot stroke, and while its full power was never developed, it supplied something like 1250 horse-power while in operation at the Exhibition. The length of the beams, between centres, was twenty-five feet, the diameter of the crank shaft was nineteen inches, and the diameter of the fly-wheel was nearly thirty feet. The revolutions of the Centennial engine per minute amounted to thirty-six, and it may be of interest to know that the total number of revolutions made during the exhibition was 2,355,300.

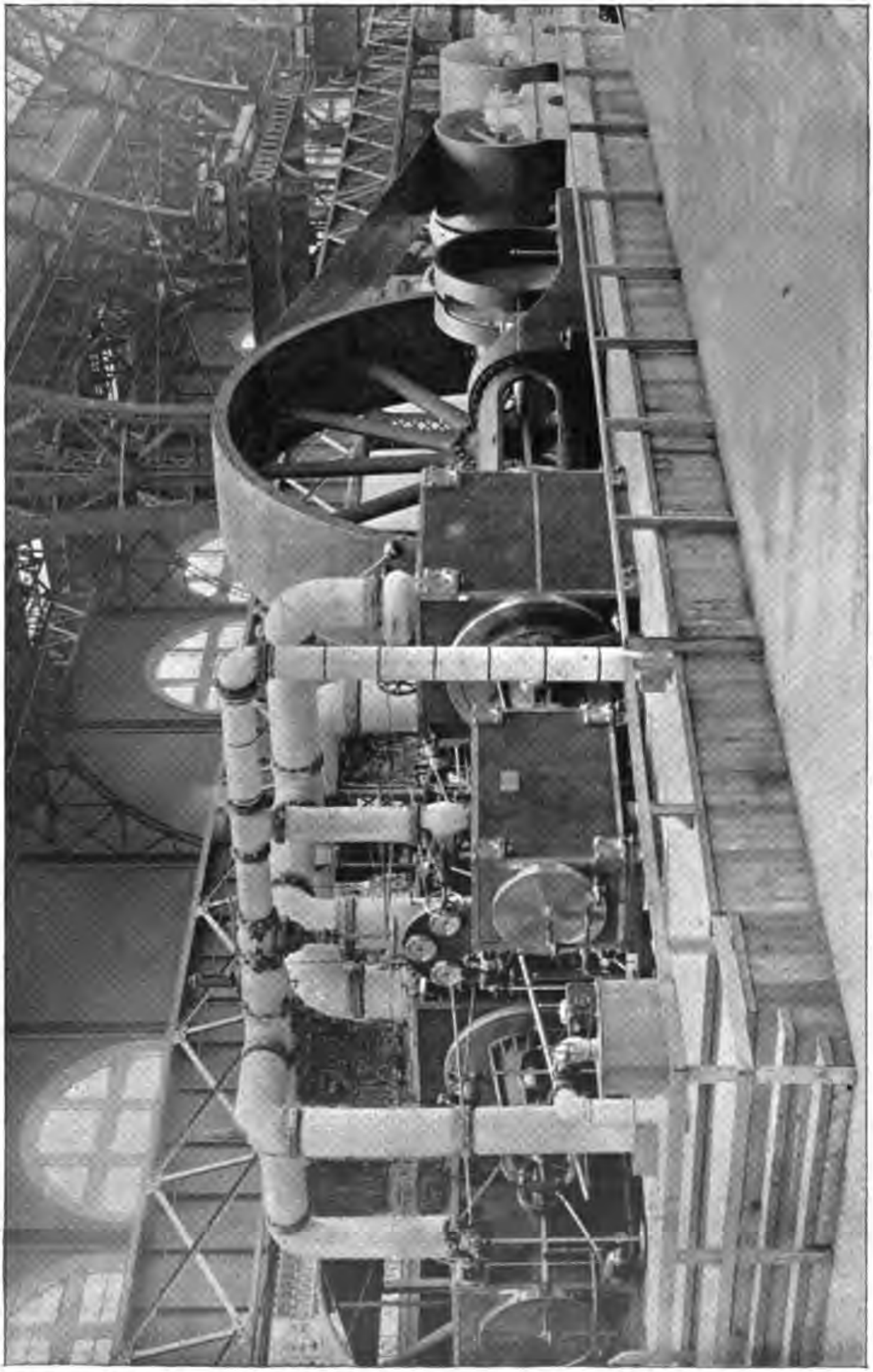
The duty of the World's Fair engine will, however, be of a different nature from that of the Corliss engine at the Centennial, which transmitted its power



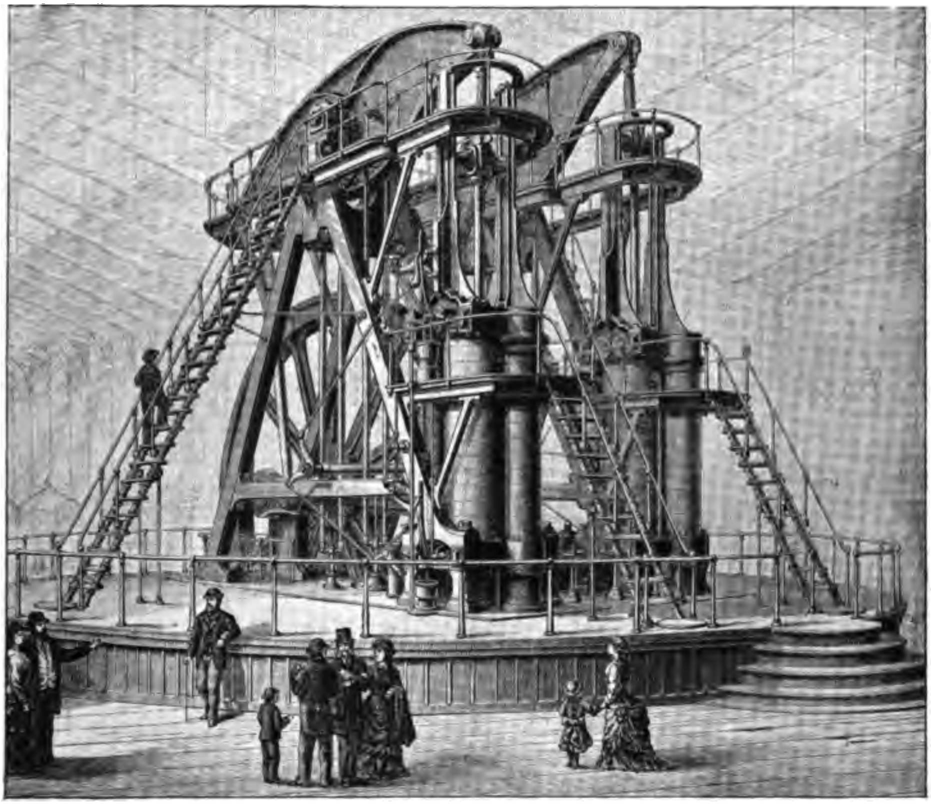
FIGS. 1 AND 2.—THE ALLIS QUADRUPLE EXPANSION ENGINE—PLAN AND ELEVATION.

to the main jack shaft. The Allis engine is belted by two belts made by the Page Belting Company, of Concord, N. H., to two Westinghouse dynamos, each of a capacity of 10,000 incandescent light. The speed necessary for these machines to produce 20,000 light of sixteen candle-power is 200 revolutions. The illustration shows only one belt, but when completed the second belt will be directly over the first connected to the second dynamo immediately beyond. The fly-wheel is thirty feet in diameter, and at sixty revolutions, will have a periphery speed of over 5500 feet per minute. The face of the wheel is seventy-six inches, not as large as many others the Allis Company have built, but in construction it is probably stronger than any of its size ever made. It has twelve arms and the rim is made up of the same number of segments. It weighs complete 135,900 pounds, the rim itself weighing 88,000 pounds.

The engine is of quadruple-expansion arranged in the form of a pair of tandem compounds, with cylinders twenty-six, forty, sixty and seventy inches in diameter by seventy-two inch stroke. It will be observed from the accompanying illustration that a belt wheel is used instead of a rope wheel, a belt wheel having been considered more distinctively representative of American practice, and the belt also, a more durable device for power transmission. To many foreign visitors, the two belts will be a source of surprise, for most large powers abroad are transmitted by ropes. In Machinery Hall but one engine transmits its power in that way, and that is of English manufacture. This seems that notwithstand-



QUADRUPLE EXPANSION CORLISS ENGINE AT THE WORLD'S FAIR, DESIGNED BY EDWIN REYNOLDS. BUILT BY THE E. P. ALLIS CO., MILWAUKEE, WIS.

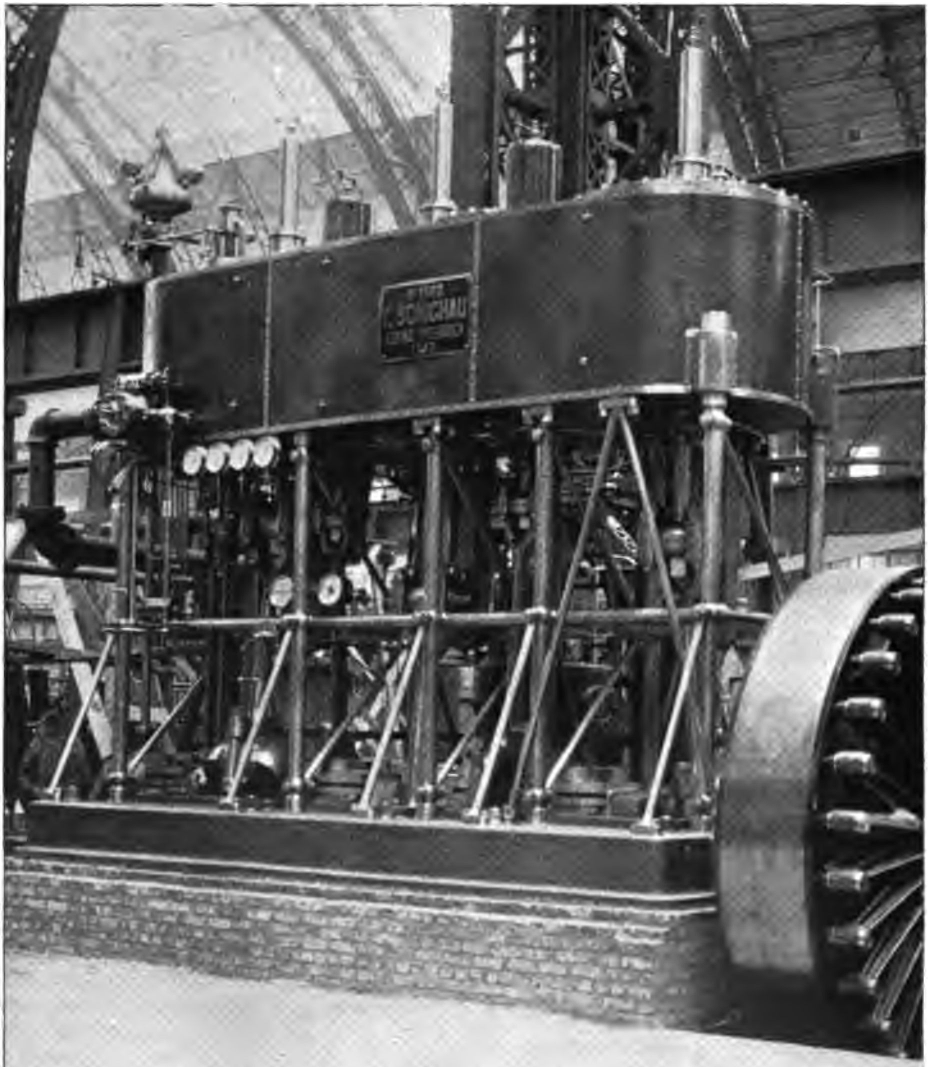


THE GEORGE H. CORLISS ENGINE AT THE CENTENNIAL EXPOSITION, PHILADELPHIA, 1876.

ing the many advantages claimed for rope, American engineers do not think anything superior to leather belts.

The Allis engine is expected to work with a minimum economical load of 2000 horse-power, and to have an economical range of from 2000 to 3000 horse-power. The entire power of the engine, however, will, as stated, be absorbed by the two Westinghouse generators. It seems proper to state here, that while the engine is certainly one of commanding size and power, it is by no means the largest engine ever built, nor the largest built at the Allis works; compared with the Centennial Corliss engine it is much the larger machine, and also an engine of much more economical type. Under the most favorable circumstances there is thought to be little doubt that this engine would deliver a horse-power for less than twelve pounds of steam per hour.

The display of the Lane & Bodley Company, of Cincinnati, O., at the Exposition consists of three horizontal Corliss engines—a simple, a tandem-compound, and a cross or twin compound. The cross compound represents their latest design. The girder is of box section and with the main box and slide support is in one casting. The slides are bored to a large radius giving a very large wearing surface for the crosshead on the slides. The design is remarkable for stiffness and has been developed to meet all the requirements of electrical engineering. The cylinders are made without the usual square corners, eliminating this unnecessary finish. The bonnets and caps



TRIPLE EXPANSION ENGINE, BUILT BY F. SCHICHAU, EBLING, PRUSSIA.

are made with round flanges and the legs or pedestals under the cylinder, usually detachable, are cast with it. The steam chamber in the top of the cylinder is unusually large. The engine has sixteen by thirty-one by forty-two inch cylinders, and is designed to run at seventy revolutions per minute. The main shaft is nearly eight inches in diameter. The steam pipe is five inches in diameter, and the exhaust pipe to the condenser measures ten inches. The steam ports in the high pressure cylinders are seven-eighth inches, and the exhaust ports 1 7-16 inches wide, and both are sixteen inches long. The steam and exhaust ports of the low pressure cylinders are respectively 1 15-16 and two and a quarter inches wide and thirty inches long. The crank pins are 4 7-16 inches in diameter and five inches long.

The tandem engine, of which an illustration is shown, is made from the old patterns. The cylinders are sixteen inches in diameter, high pressure, twenty-nine inches low pressure, and forty-two inches stroke, and are attached to a specially heavy girder frame. The main bearing of the shaft is 10 15-16 inches in diameter. This engine is furnished with the low pressure cylinder next to the girder, and a very neat trunk connection between the two cylinders. The receiver on both the tandem and the cross compound engines is arranged below the floor. The third engine is a simple engine, having a cylinder eighteen inches in diameter and of forty-two inch stroke. The girder is made with a ribbed section forming three sides of a box. The governor on this engine is of the Hartnell type, well known in connection with this engine, and which has proven very successful in delicate regulation and durability. The engines are splendid specimens of design, having neat lines, and are evidently built for hard service. Their proportions are such as will adapt them successfully to electric lighting and railroad service.

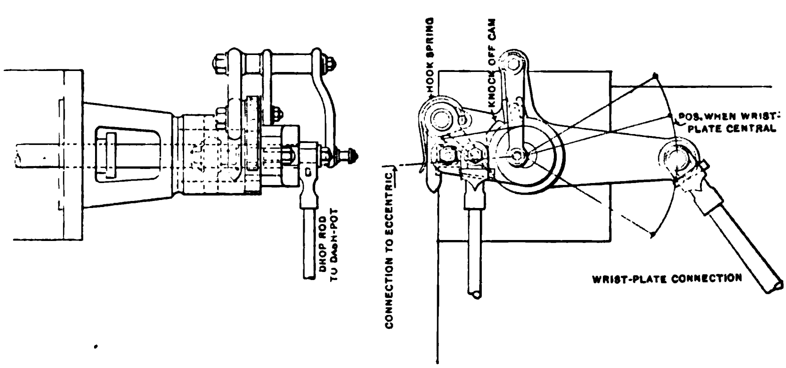
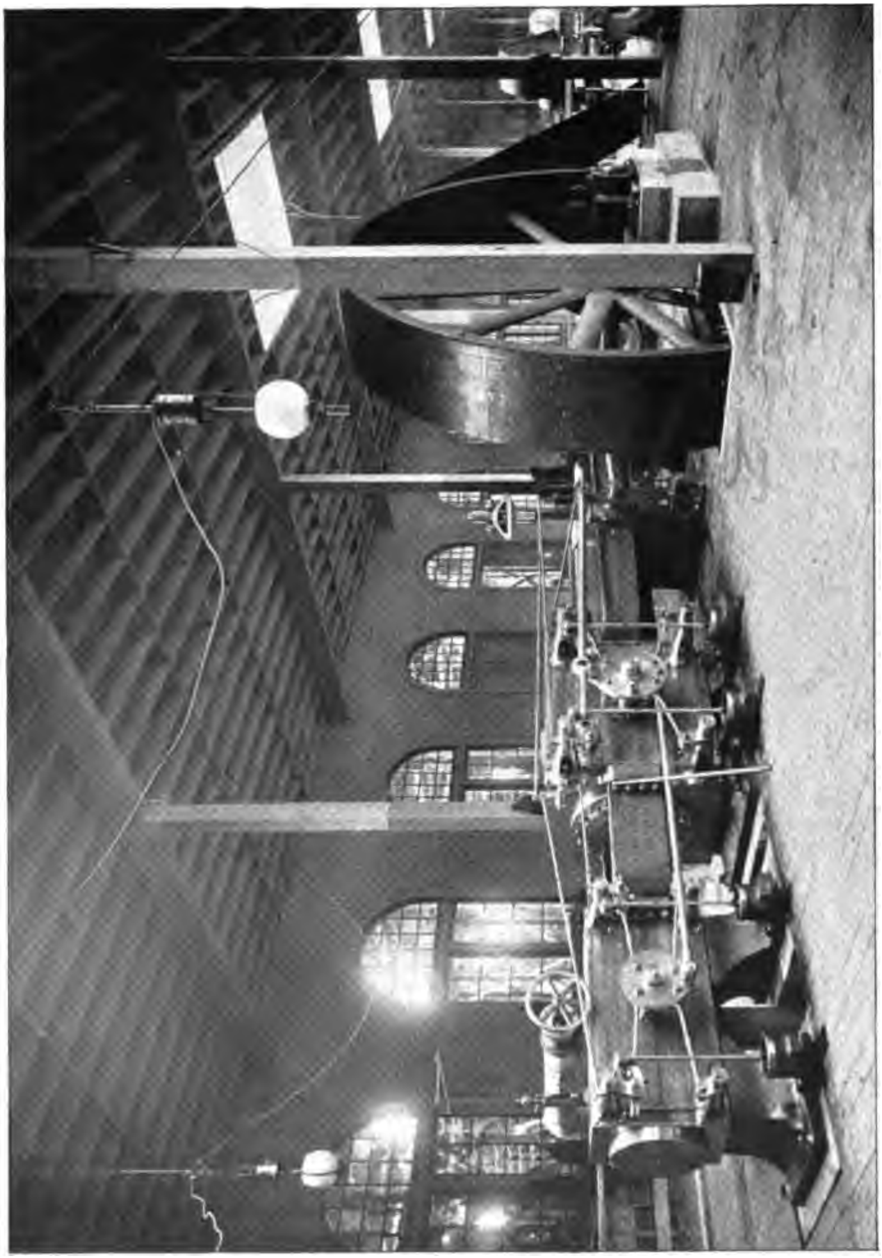


FIG 3.—DETAILS OF VALVE MECHANISM—ALLIS WORLD'S FAIR ENGINE.

In the way of foreign engines, an interesting type is shown by F. Schichau, of Ebling, Prussia. This engine is 22¾ x 37½ x 57¼ x 27½ inches vertical, triple-expansion condensing, with three cranks, and at 100 revolutions per minute is rated at 1000 horse-power. At a speed of 180 revolutions per minute the power runs up to 2500 horse-power. Steam is to be used at a pressure of about 180 pounds per square inch. This type of engine is built specially for marine service, but the one shown is connected direct to a Siemens & Halske dynamo. The cylinders are set on steel columns, suitably braced, and the whole makes a very light engine considering the power developed, the weight not exceeding 143,000 pounds.

The shaft is of Krupp steel, twelve



TANDEM COMPOUND CORLISS ENGINE, BUILT BY THE LANE & BODLEY CO., CINCINNATI, O.

inches in diameter, and is one solid forging. The air pump for the engine is direct connected, and is thirty-four and one-half inches in diameter by thirteen inch stroke. The condenser is formed by the exhaust pipe running toward the air pump and the injection pipe running up into the exhaust pipe and meeting the steam. The high-pressure cylinder has two eccentrics, one working the main piston valve, and the other controlling the cut-off valve which is inside the main valve and which is rotated by the action of the governor, shortening or lengthening the cut-off by opening or closing helically formed ports in the main valve. The intermediate and the low-pressure cylinders each have one eccentric connected to balanced slide valves, and the strains on the eccentric rods are reduced by small auxiliary piston attachments. The first two cylinders have steam jackets supplied with steam at boiler pressure, and the jackets have small air valves to prevent air binding, and traps for draining off the water of condensation. The low-pressure cylinder is not jacketed. The piston rods are guided at both ends, extending through the upper ends of the cylinders. The crank pin boxes are of brass lined with Babbitt metal, this being true also of the main bearing, but the cross-head ends of the connecting rods are forked and the brasses are not lined. The engine is thoroughly fitted up with gauges, counters, etc., and presents a finely finished appearance.

Another German engine exhibited and worthy of note is one of the semi-portable type built by R. Wolf, of Magdeburg, Buckau. This is a forty horse-power nominal, compound condensing engine, capable of indicating up to seventy-five horse-power. The cylinders are 260 and 430 millimeters (ten and one-quarter and about seventeen inches) in diameter and have a 400 millimeter (sixteen inch) stroke. The total heating surface of the boiler is 36.2 square meters, or about 390 square feet. The engine works at a speed of 110 revolutions per minute.

The Wolf engines have become very well known on the European continent and their export is said to be increasing every year. Quite a large number of them have gone to South America, to Africa, and even to China and Japan. They are very substantially built and, like many of English make also, are quite different from most of the engines known in the United States as semi-portable engines. In this country, as a matter of fact, the manufacture of the semi-portable type of engine has received comparatively little attention, and it can scarcely be said to have thus far appealed to the general power user as an economical or a desirable motor. In England, and on the European continent, on the other hand, semi-portable engines have for years occupied a position of prominence, and their design and construction have been carried out with much care and attention to the requirements of economy and durability.

One of the distinguishing features of the Wolf outfit is the separable character of the boiler. The latter is of the tubular form, and is so made that the whole tube system may be easily drawn out of the boiler shell for ready cleaning, examination and repairs. How important and desirable a feature this is need scarcely be pointed out; it will be appreciated at once by all steam users, and especially those who have to deal with dirty water for steam raising. In order to extract the whole bundle of tubes, it is only necessary to loosen a few nuts in the smoke-box end of the boiler which connect the front plate with the outer shell, and a few nuts on the fire-box end which hold the back tube plate to the back plate of the boiler. This having been done, the boiler readily separates into two parts.

The so-called locomotive boilers of the ordinary run of portable and semi-portable engines do not permit of such separation, as is well known, and the interior of the boiler cannot, as a consequence, be got at without much trouble, if at all. When the nest of tubes, however, can be withdrawn from the shell, the whole interior of the boiler can be laid open to daylight and all parts can

SEMI-PORTABLE ENGINE AND BOILER, BUILT BY R. WOLF, MAGDEBURG, BUCKAU, GERMANY.

be made accessible so that thorough and reliable cleaning can be insured.

Another distinguishing feature of the Wolf engine is the disposition of the cylinders inside the dome of the boiler by which long steam pipe connections are dispensed with and ample protection is afforded against loss of heat and condensation. The boiler itself is wholly enclosed by a double, non-conducting covering with an intermediate air space, so that very little loss is likely to occur from radiation. As a matter of fact, the economy of the Wolf engines has become well established abroad, and their steam consumption is claimed to be quite as low as that of many of the best stationary engines. An official test in Germany, a short time ago, of an engine like that illustrated is said to have shown a coal consumption of only two and a quarter pounds of coal per horse-power per hour.

Coming back once more to the details of the engine proper, it should be explained that the high-pressure cylinder is fitted with the Rider automatic expansion gear, while the low-pressure cylinder has simply an ordinary slide valve expansion gear adjustable by hand. The intermediate receiver as well as the two cylinders are placed inside the dome of the boiler. The condenser is an injector condenser placed vertically by the side of the engine and

is connected by a horizontal tube to the air pump which is arranged underneath the crankshaft of the engine. The plunger piston of this air pump is driven directly from the crankshaft by means of an eccentric. The engine is provided with a geared Porter governor which acts by means of an arm on the expansion slide of the Rider gear. The gears are cut by special machinery and work smoothly and noiselessly.

The regular compound condensing and non-condensing stationary engine turned out by the same maker is, in the main, similar in design to the engine used in the semi-portable outfit. The lubrication of the cylinders is effected by means of a mechanical oil pump, which conducts the lubricant continually, in a state of fine division, into the cylinders, and which may be regulated according to momentary requirements. Steel enters largely into the construction of the engines with the view of keeping down the weight. The fly-wheels are turned and finished, and fitted for either belt or rope driving as desired. The engines are specially designed for industrial installations of all kinds, particularly for driving dynamos, and are supposed to take the places of the large Wolf semi-portable engines where difficulty of transportation or other circumstances do not permit the erection of those. Simple automatic and throttling engines are also built by the same firm, the Rider expansion gear and Porter governor being applied in the former, while in the latter the cut-off may be varied by hand, a Buss governor being used.

A four-cylinder, triple-expansion engine, of nominally 1000 horse-power, but able to develop about 1500 horse-power under 150 pounds steam pressure or more, is exhibited by the Buckeye Engine Company of Salem, O. It is a condensing engine, and is fitted with a Wainwright surface condenser located under the floor.

Steam is first used in the high-pressure cylinder, whose dimensions are twenty inches diameter by forty-eight inches stroke. From this it passes through a reheating receiver to the intermediate cylinder, which is on the other engine, and whose dimensions are thirty-two and one-half inches diameter by forty-eight inches stroke. From this it passes again through a reheating receiver, from which it divides into two pipes, each connecting with a low-pressure cylinder, one on each engine, the cylinders being thirty-six inches in diameter by forty-eight inches stroke. The reheating receivers are under the floor, and all pipes pass directly downward through the floor, making a very neat appearance.

The fly-wheel is twenty feet in diameter by seventy-five inches face, and has two sets of arms, making twenty arms in all. This is a very stiff and strong construction, noticeably so in view of the fact that a good many large wheels have been wrecked within the last year, owing to faulty construction on one hand, and running away of the engine through some sudden decrease of load on the other. The belt driven by this engine is seventy-two inches wide and has a velocity of a little more than a mile a minute.

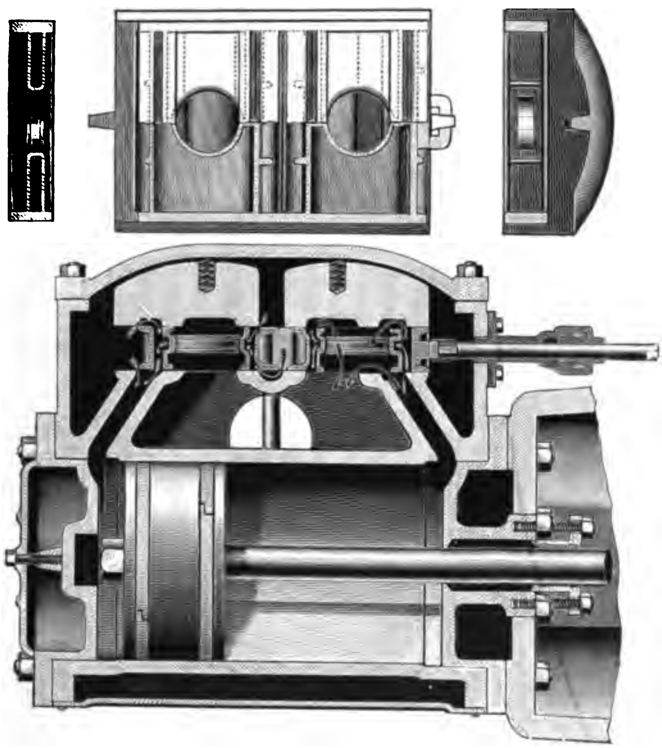
The high-pressure cylinder is provided with a piston valve, which contains also a piston valve whose sole duty is to cut off the steam at the proper point. The other cylinders are each provided with the well-known Buckeye hollow valve, containing an independent cut-off. The engine has two governors, and is so arranged that if either half is disabled, the other half may be run independently.

Among the other engines shown by the same builders is a cross compound condensing engine of their medium speed type, having two cylinders fourteen by twenty-four inches and twenty-eight by twenty-four inches, and producing about 325 horse-power under the conditions under which it is working.

They have on exhibition also a thirteen by twenty-one inch medium speed engine, running non-condensing, of about 130 horse-power; a high speed engine, running non-condensing, cylinder thirteen by sixteen inches, also of

FOUR CYLINDER TRIPLE EXPANSION ENGINE, BUILT BY THE BUCKEYE ENGINE CO., SALEM, O.

about 130 horse-power, and a slow speed engine of the Corliss type of bed plate, also running non-condensing, having a cylinder sixteen and one-half inches diameter by thirty inches stroke and producing about 180 horse-power. Next to this is a high speed tandem-compound condensing engine, having cylinders eleven by sixteen inches and twenty-one by sixteen inches, and producing about 185 horse-power.



THE VALVE OF THE WATERTOWN AUTOMATIC ENGINE.

The Buckeye Company build engines of three types: High speed (short stroke), medium speed (medium stroke), and slow speed (long stroke), so as to be able to supply engines for all possible requirements. Each of these varieties they compound in all the four ways, viz., tandem condensing, tandem non-condensing, cross condensing, and cross non-condensing. Of this variety they show at the Exposition, working with full loads, as intimated in what has already been said, simple non-condensing engines of each of the three varieties, as well as a tandem-compound condensing engine of the high speed type, a cross compound condensing engine of the medium speed type, and a cross triple-expansion engine of the slow speed type, making in all six engines, or, considering that some of these are double, making in fact eight engines.

To this exhibit they will add a small working model engine not more than fifteen inches long, complete in all details; also a sectional model, running at very slow speed, in order to show clearly the action of the valves and valve gear. This is made by cutting the cylinder and valves through longi-

DUPLEX TANDEM COMPOUND AUTOMATIC ENGINE, BUILT BY THE WATERTOWN STEAM ENGINE CO., WATERTOWN, N. Y.

TANDEM COMPOUND ENGINE, BUILT BY THE PHŒNIX IRON WORKS, MEADVILLE, PA.

tudinally, and it will unquestionably be a very interesting feature to engineers or men who use engines.

The large Buckeye engine, first referred to, is completely equipped with U. S. metallic packing as an exhibit of the manufacturers of this packing. It should be added also that the pistons of the large engines are made of steel for the sake of increased strength and lightness. The tandem-compound, high speed engine has been running in the temporary power plant of the Exposition during the past eighteen months.

A duplex, tandem-compound condensing engine of new design is shown by the Watertown Steam Engine Company, of Watertown, N. Y. It has two nine-inch high-pressure, and two sixteen-inch low-pressure cylinders, all of fourteen-inch stroke. In the governor of this engine, unlike other shaft governors which secure a varying cut-off by shifting a single eccentric across the shaft, the movement is obtained by a mechanism which is, in effect, a double eccentric turning on the shaft. Particular attention is called to the fact that its effect is to increase the steam lead as the load on the engine is increased and as more steam is needed ;

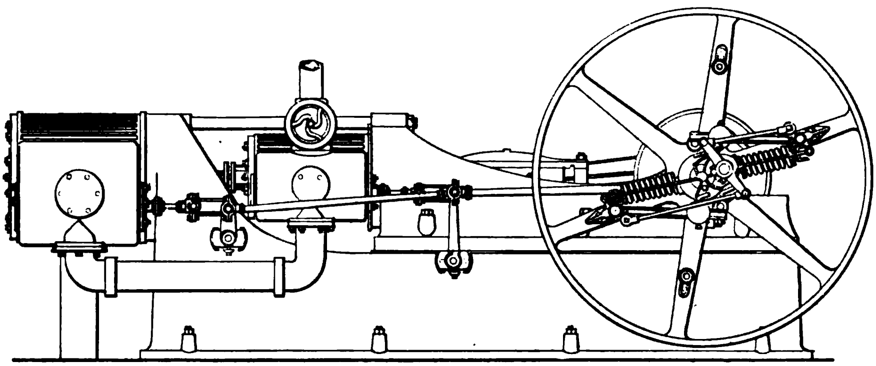
on the other hand, as the load falls off, less steam is required and the steam lead is decreased, with the further result of reducing compression. The governor in this engine, it should be observed, is the same in principle and action as the regular Watertown engine governor used in the other automatic engines of the company.

The valve, of which a sectional view is given, is also of the regular Watertown design, and has port openings so arranged as to admit steam to the cylinder ports through four different openings at once, thus giving a port opening four times the travel of the valve and securing very prompt action upon piston. The valve also exhausts steam through four openings at once. The valve is accurately fitted to its place and is carefully scraped. On the back of the valve is a pressure plate, balancing the valve so easily, it is claimed, that it can be worked readily by one hand while under steam. This pressure plate is held in its place by a small spring at the back, holding it to its position in spite of wear and acting also as a relief valve when excessive pressure from water in the cylinder throws the valve from its seat. The valves of all four cylinders are controlled by the governor, insuring an even division of the load.

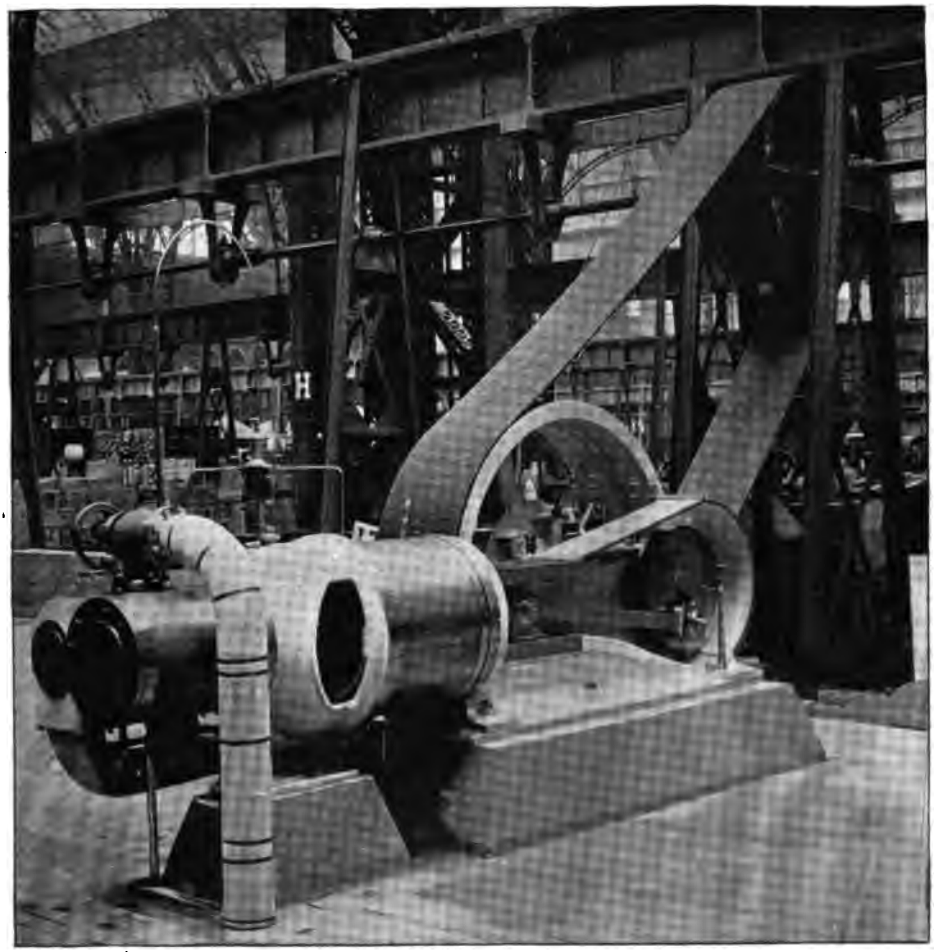
All the cylinders are neatly jacketed with closely fitting iron staves. The cylinder heads also are jacketed, and the spaces between the high and the low-pressure cylinders are covered by extensions of the high-pressure cylinder jackets. The removal of a single panel at any time gives easy access to the stuffing-boxes and cylinder heads. The whole engine, which runs in conjunction with a Knowles condenser, is mounted on a neat and substantial sub-base, with an extension on which are fitted supports for the high-pressure cylinders. These supports are so made that they can be adjusted not only horizontally, but also vertically, to meet any possible movement of the high-pressure cylinders due to expansion under heat.

The frame of the engine is very heavy, with longitudinal and cross ribs securely bracing it. The working parts are placed as low as possible, bringing the centre lines at about the surface of the bed, so that all the strains are brought in line with the lines of greatest resistance. All oil from the cross-heads, connecting rods, and cranks is caught in the bottom of the frame, whence it can be drawn off. The crank shaft is slotted from a solid, forged block. The connecting rods are of forged iron with square straps and boxes, the latter being of composition metal. The cross-heads are made of crucible steel, and have large bearing surfaces, both cross-heads and guides being carefully scraped.

Besides the engine shown, the builders turn out a single-cylinder, high speed, automatic engine, a cross com-



SIDE ELEVATION PHŒNIX IRON WORKS TANDEM COMPOUND ENGINE.



TANDEM COMPOUND ENGINE, BUILT BY THE HARRISBURG FOUNDRY AND MACHINE WORKS, HARRISBURG, PA.

pound, and a plain tandem-compound. They are also prepared, however, to build triple-expansion engines of from 200 to 500 horse-power.

The Phœnix Iron Works Company, of Meadville, Pa., show one of their latest designs of tandem-compound, Dick and Church engines. Heretofore, in engines of this type, the rear cylinder, or the one farthest from the main shaft, has usually been attached to the forward cylinder, which, in turn, was suspended from the bed frame of the engine. In the engine shown, however, the low-pressure cylinder is carried on a separate bed frame which forms the sub-base for the main engine. The cylinders thus being on separate bed frames, the overhanging of both cylinders from one bed frame is done away with. This construction is claimed to be not only more rigid, but to allow each cylinder to expand independently of the other, always preserving the alignment; it also renders either cylinder easy of access without disturbing the other. The hoods which carry the overhanging cylinders are rigidly tied together by a rod which extends from one to the other, over the top of the high-pressure cylinder.

The valve gear is so constructed that

the valves of both cylinders are controlled automatically by the one governor, a new and valuable feature in engines of this class, and which gives practically a regular receiver pressure and proper distribution of load and temperatures between the two cylinders at all points of cut-off. This peculiar feature is of special value in non-condensing engines working under variable loads. Great care has been taken in designing this engine to have ample wearing surfaces and large heavy wheels, to make the proportions such as to meet the requirements of extreme and variable loads, such as are met within electric railway service. These engines are also made in the double tandem compound and triple-expansion types.

The exhibit of the Harrisburg Foundry & Machine Works, of Harrisburg, Pa., consists of two engines driving line shafting. One of these engines is the company's standard Ide pattern, automatic, tandem-compound, side-crank engine, with outboard bearing. The cylinders of this engine measure seventeen and twenty-eight inches in diameter, and have an eighteen-inch stroke. The engine is rated at 300 horse-power, when running non-condensing, and at a speed of 180 revolutions per minute. The fly-wheel pulley is 102 inches in diameter and has a thirty-one inch face. Both the high and low pressure valves are adjustable piston valves, designed by Mr. M. E. Hershey, the general manager of the company, and each is worked by a separate eccentric. The high pressure valve is controlled by the fly-wheel governor, while the low pressure valve is made adjustable by hand to meet the varying conditions under which the engine might be called upon to work.

The other engine shown by the company is the Harrisburg Ideal tandem-compound, with one fly-wheel pulley, 102 inches in diameter, with an eighteen inch face. A second main driving pulley is made of the same diameter, but with a thirty-one inch face, and has a special, outboard bearing. The valves are worked from eccentrics on opposite sides of the engine, the high-pressure valves being controlled by the automatic governor, and the low-pressure valve by an independent, adjustable eccentric. Both valves are of the same design as those used in the engine just described. The cylinder capacity, power and speed of the engine are also the same.

A twelve by twelve inch Ideal self-oiling engine is to be placed by the side of the larger engine, without any anchorage to a foundation. The engine is to be raised about six inches from the base plate, and is to be supported on three points. In this condition the engine will be run up to a speed of 300 revolutions per minute to show its perfect balance, and the special adaptability of this type of engine for electric light work where cleanliness, quiet running, and balance of all running parts are particularly desirable.

(*To be continued.*)

AMOUNT OF WATER SUSPENDED IN STEAM.*

By W. R. Cummins.

THE object of this paper is to raise a discussion on the different methods adopted at engine and boiler trials for measuring the amount of water suspended in the steam supplied to the engine. In the first place, the writer considers it almost unnecessary to point out the enormous value of engine and boiler trials, such as those carried out during the past few years by the Institute of Mechanical Engineers.

Trials of this kind, if properly carried out, have a use quite apart from their scientific interest, as they enable the engineer to see the weak points in the system under trial, point out in what manner it is better than that which it has superseded, and, most important of all, indicate the direction in which further improvement may be made.

To obtain a real comparison between different types of engine and boiler, it is very necessary to separate the different efficiencies which go to make up the total efficiency of any combination. The efficiency of a boiler is made up of the efficiency of the furnace and the efficiency of the heating surface. The efficiency of an engine is made up of the efficiency of the steam and the efficiency of the mechanism. The measurements usually made at trials of marine machinery are: Weight of coal burnt, analysis and calorific value of coal, analysis and temperature of funnel gases, indicated horse-power, weight of water pumped into the boiler, and amount of "priming" water delivered to the engines. In the opinion of the writer this last measurement is of the greatest importance, as, without it, it is impossible to separate the efficiency of the engine from that of the boiler, and, moreover, all calculations as to the condensation and re-evaporation in the cylinders, effect of jackets, etc., can only be based on guesswork.

A notable instance of how priming may vitiate trial results occurred at the Mechanical Institute's trial of the steamship Tartar. No means were taken at this trial for measuring the amount of priming, the steam being assumed to be practically dry. On making the calculations after the trial it was found that the efficiency of the boilers was unexpectedly high, and that of the engines unexpectedly low (on the assumption that all the water pumped into the boilers was turned into steam). A very complete analysis of the waste gases, however, had been made, which enabled the research committee to state that a considerable amount of priming had taken place, probably amounting to about twenty per cent. of the total feed.

In this instance the amount of water present in the high-pressure cylinder amounted to no less than fifty-five per cent. of the total steam and water passing through it; and on referring to the reports of the other trials it will be seen that the amount of water present at various stages often reaches forty or fifty per cent., and this water is all, or nearly all, suspended in the steam in a very fine state of division, as is seen when the indicator cock is opened and the mixture of steam and water allowed to blow through it.

The lessons taught by this trial are: (1) that it is impossible to gauge the wetness of steam by its apparent condition at the indicator cock, and (2) that the ordinary marine boiler may under no apparent provocation deliver steam containing twenty per cent. of water. May this last fact not also throw some light on the otherwise inexplicable anomalies as set forth in the recently

*Read before the Northeast Coast Institution o Engineers and Shipbuilders, Glasgow, Scotland.

published report of the research committee on the "Efficiency of Steam Jackets"?

Before proceeding to describe the various apparati, it might be well to make some inquiry into the nature of priming. Priming may be due to two actions, the first of which may be described as being entirely mechanical—that is to say, the particles of water projected into the steam space of a boiler by the ascending bubbles of steam become wholly or in part suspended in the steam. The second cause is due to insufficient absorption of heat, which latter may be due to two causes. Take the case of an isolated drop of water at the same temperature as the steam. This drop may receive enough heat to turn the whole of it into steam, and may take up a certain quantity of water before it reaches the steam space, or it may reach the steam space without having received sufficient heat to turn the whole of it into steam.

It does not seem possible to estimate how much each of these causes affects the total amount of priming, but it seems probable that the second cause should depend upon the disposition of the heating and water surfaces and the temperature of the gases, and that the erratic nature of priming is due to the first mentioned cause.

The presence of grease in a boiler often causes priming. Can it be that greasy steam is capable of holding more water than clean steam? Perhaps particles of grease in the steam space act as nuclei round which water will collect.

Among the first attempts to measure the water contained in steam was that by means of an apparatus called the "barrel" calorimeter.

It consists of a vessel (probably originally a barrel, hence the name) containing a known weight of water at an observed temperature. The steam to be tested is led to the bottom of the vessel, thus passing through the water and becoming condensed. At the end of the test the increases of weight and of temperature are noted, and from these data and a table of the properties of steam the amount of water in the steam may be calculated.

This apparatus has many disadvantages. In the first place, a correction must be made for radiation from the apparatus and for the amount of heat absorbed by it; and, in the second place, a correction must be made for any evaporation which may take place from the surface of the water.

Although this latter may be neglected if the final temperature be kept sufficiently low, the corrections for radiation and absorption present a good many difficulties, entailing tests on the apparatus to determine the loss of heat under varying conditions, such as different temperatures of atmosphere and different durations of test.

The greatest disadvantage of this apparatus, however, for use on board ship would be the difficulty of weighing with sufficient accuracy.

The next method to be considered is that of the salt test, which is carried out as follows:—A sample of water is taken from the boiler, and the percentage of salt held in solution is determined with great accuracy. A sample of steam from the steam pipe is at the same time collected in a small special condenser, and the percentage of salt in it is determined by chemical analysis, as in the case of the water from the boiler. From these data the amount of priming water may be calculated.

This method should give accurate results for what the writer has called "mechanical" priming, provided the sample of water were taken from the right place,—viz., near the water surface,—but it is not at all certain that it would give reliable information as regards the other kind of priming; in short, the truth of the result of the calculations depends upon the assumption that the whole of the salt in solution is precipitated at the moment the water assumes the gaseous form.

Take the case of an isolated drop of water at the temperature of evaporation, and suppose it to contain five per cent. of salt in solution. Let it receive enough heat to turn three-fourths of it into steam, then if at the moment of

gasification the drop of water contained five per cent. of salt, the resultant steam would contain $5 \div 4 = 1\frac{1}{4}$ per cent. of salt. If, on the other hand, some of the salt were precipitated before the moment of gasification—suppose, for instance, that two and one-half per cent. were thus precipitated—then it is evident that the steam would only contain five-eighths per cent. of salt instead of one and one-fourth per cent. as before. The writer is not aware of any experiments on the behavior of salt in a solution of water subjected to gradual heating and evaporation; but if the whole of the salt does not remain in solution until the moment of gasification, then the results will be inaccurate to an extent which cannot be easily estimated, as it depends upon two factors—first, the proportion of each kind of priming; and, secondly, the amount of precipitation before gasification. In this connection it will be well to note the length of time the water remains in the boiler. Take the case of the mechanical engineers' trial of the paddle steamer, Ville de Douvres. The boilers contained $61\frac{1}{2}$ tons of water $= 137,760$ pounds. Total feed per hour $= 66,180$ pounds, $137,760 \div 66,180 = 2$ hours about.

It is thus easy to imagine that at any moment there may be a certain portion of the water in the boiler—viz., that which is on the point of being turned into steam—containing a less percentage of salt than the body of water from which the sample is taken. Another source of error may be introduced when more than one boiler is supplying steam and only one condenser is used on the main steam pipe, for it is evident that if the boilers have different percentages of salt, and one boiler does more priming than the other, an error will be introduced. Hence, when more than one boiler is in use, a separate sample should be taken from each branch pipe. Taking these points into consideration, it appears to the writer that the salt test would not be sufficiently reliable for accurate results, the probability being that the amount of water in the steam would be under-estimated.

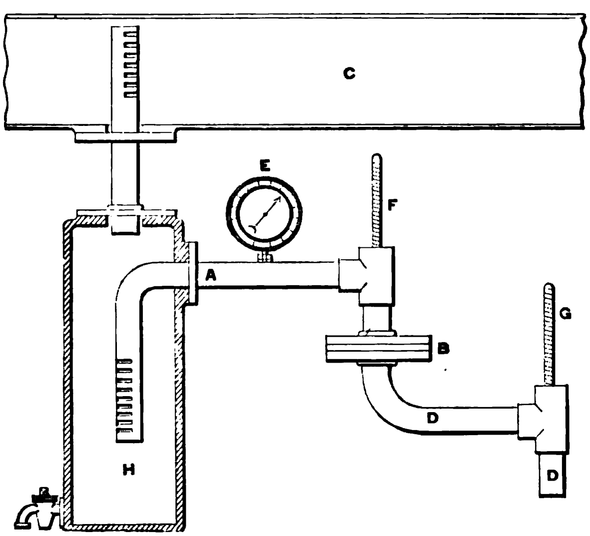


FIG. 1.—APPARATUS FOR DETERMINING AMOUNT OF WATER IN STEAM

The next apparatus to be considered is the Barrus calorimeter. The action of this instrument is based on the fact

that if steam be allowed to expand without doing external work, it will become superheated; that is to say, the heat which would be transformed into work if the steam were expanding and doing work on a piston, is expended internally, viz., by heating itself, or by evaporating any contained water.

The apparatus consists of a tube A (see Fig. 1) having its end closed by a diaphragm B, perforated with a small hole. The steam to be tested is led from the steam pipe C to the tube A, from whence it escapes to the atmosphere through the small hole in the diaphragm by means of the tube D.

A pressure gauge E and thermometer F are inserted in the tube A, and a thermometer G in the tube D. Suppose the steam to be of 150 pounds pressure: then if it were dry, saturated, and no heat were lost by radiation, the amount of heat available for superheating would be $1225 - 1178 = 47$ thermal units = difference of total heat of steam at 150 pounds pressure, and steam at atmospheric pressure. Specific heat of superheated steam = 0.48. Hence amount of superheat $= \frac{47}{0.48} = 98$ degrees Fahrenheit approximately. So that the thermometer in the tube D would indicate $212° + 98° = 310°$ Fahrenheit.

Next, suppose the steam to contain five per cent. of water, then total heat of steam and water at 150 pounds pressure $= (0.95 \times 1225) + (0.05 \times 370) = 1182$ thermal units. Total heat at atmospheric pressure if all water be evaporated = 1178 thermal units. Difference = 4 thermal units, available for superheating. Amount of superheat $= \frac{4}{0.48} = 8$ degrees Fahrenheit. Hence thermometer in tube D would indicate $212 + 8 = 220$ degrees Fahrenheit.

It will be seen at once that this apparatus is very sensitive to small variations in the percentage of contained water. For example, with steam of 150 pounds pressure there is a difference of ninety degrees Fahrenheit for five per cent. of water, but, on the other hand, it has only a limited range; for instance, with steam of 150 pounds pressure the range is limited to about five per cent. of water, without taking account of radiation, as six per cent. of water reduces the heat available for superheating to a negative quantity, and at eighty pounds pressure the range is practically limited to three per cent. of water.

An attempt has been made to get over this difficulty by fitting what is called a "drip box" H, as shown in Fig. 1, the function of which is to intercept as much as possible of the contained water.

The water collected in this box is drawn off at intervals and weighed, and the proportion which this latter bears to the total quantity of steam passing through the instrument is added to that calculated from the amount of superheat.

The quantity of steam passing through the small hole is determined by experiment for each apparatus, the steam being led to a condenser, collected, and weighed. This seems to be a very rough and ready way of calculating what, in a great number of cases, will be the greater proportion of the contained water, unless very careful experiments are made to determine the weight discharged under every condition of steam pressure, atmospheric pressure, and wetness of steam. This defect, however, could be remedied by always using a condenser in connection with the apparatus, and the addition of an air pump for maintaining a vacuum in the condenser would increase the range of the instrument; thus for steam of 150 pounds pressure and a vacuum corresponding to two pounds absolute pressure, the range would be increased from about five per cent. of water to about eight per cent. of water. It seems probable that the drip box under certain conditions would not be able to intercept a sufficient proportion of the suspended water. In this case a centrifugal separator might be used to replace the drip box.

When using this apparatus a certain

allowance must be made for radiation, and the difficulty of estimating this allowance will always leave some doubt as to the correctness of the results. There is a certain amount of heat available for evaporating the moisture and superheating the steam, and this is distributed between the steam and the material of the apparatus.

If the steam be of constant quality the apparatus will after a time arrive at a normal temperature, and the only heat not given to the steam will be equivalent to that lost by radiation to the atmosphere.

If, however, as will probably be the case, the percentage of water be continually varying, the thermometer in the tube D will not give correct readings, as it will be influenced by heat given out and taken up by the material of the apparatus; that is to say, the thermal capacity of the apparatus will tend to lessen the oscillations of the thermometer G, and thus lead to erroneous results.

Taking the above points into consideration, it appears to the writer that the Barrus calorimeter should give fairly accurate results for high pressures and small percentages of water, but for low pressures or large percentages of water it would require considerable modification to make it generally useful.

In order to overcome the difficulties connected with the three methods described above, the writer has designed the apparatus shown in Fig. 2. It consists of a cylinder A filled with a number of small tubes fixed in the tube plates B. A jacket D is cast round the barrel, and the covers C form jackets for the ends.

The principle of the action of the apparatus is to evaporate the water contained in a sample of the steam under test, in a vessel of fixed volume. When all the water is evaporated the increase of pressure is noted, and a simple calculation gives the percentage of water originally in the steam.

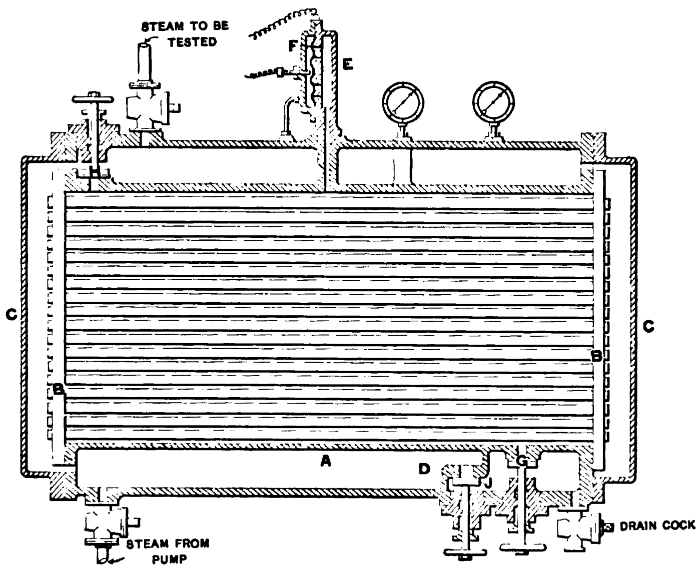


FIG. 2.—APPARATUS FOR DETERMINING AMOUNT OF WATER IN STEAM.

The heat required for thus evaporating the water contained in the sample of steam is supplied by admitting to the jacket steam of higher temperature than that of the sample in the cylinder.

When the steam to be tested is of boiler pressure, and no higher pressure is available, a small steam ram pump may be used to pump steam of the required pressure into the jacket.

The point at which all the water in the sample is evaporated is determined by the fact that superheated steam has a lower pressure than saturated steam of the same temperature. Hence, so long as the pressure of steam in the cylinder and that in the jacket (which is kept saturated) is the same, it will be known that the sample steam is saturated; but as soon as the pressure in the cylinder falls below the pressure in the jacket, then it will be known that all the water has been evaporated and the sample will be superheated.

On top of the apparatus is an attachment E for detecting very small differences of pressure between the cylinder and the jacket. It consists of a thin diaphragm F of corrugated steel, one side of which is in connection with the sample steam in the cylinder, and the other side is in connection with the jacket.

Immediately the pressure in the cylinder falls below that in the jacket, the movement of the diaphragm breaks an electric circuit and cuts out a bell.

The operation of testing a sample of steam would be as follows: First, the jacket and cylinder would be opened to the steam to be tested, so that the whole of the surfaces would be brought to the same temperature as it. The outlet valve G would then be opened and the inlet valve H closed, so that any water adhering to the surfaces would be evaporated, and enough steam blown through to ensure a fair sample of steam being in the cylinder. The outlet valve G would then be closed, and then the inlet valve H. The pressure in the jacket would then be gradually raised until the bell ceased ringing, which would indicate that all water had been evaporated.

As regards the probable accuracy of results obtained from this apparatus, the first point to be considered is the reliability of the data at our disposal on the density of saturated steam at different pressures.

This has not yet been experimentally determined, but can be calculated from the latent heat, pressure, and temperature, which latter have all been determined by Regnault.

The next question concerns the constancy of volume of the steam in the cylinder, as an error will be introduced if the volume is not constant throughout the test.

In the first place, the volume of the cylinder may vary owing to expansion by increase of temperature. This may be calculated and allowed for. Increase of pressure may cause a variation of volume due to distortion of the cylinder, but does not seem at all likely, as the cylinder will practically under an equilibrium of pressure. There may also be a variation in the volume of the pressure-gauge tube, and the motion of the diaphragm will also cause a variation which may be calculated and allowances made.

The volume occupied by the suspended water will be so small that it may be neglected. The next question is: Will the temperature of the steam in the jacket and tubes be distributed throughout the mass of the sample steam in the cylinder? There should be no doubt of this if the tubes are put sufficiently close together, and if care be taken that all surfaces exposed to the steam being tested are properly jacketed.

Leakage would be rendered impossible by brazing all joints exposed to pressure from the steam in the cylinder. The inlet and outlet valves H and G to the cylinder might present some difficulties, and in order to minimize these it will be seen that they are both so arranged that during the time of testing (the valve J being then open and the drain cock shut) the tendency to leak, which should depend upon the difference of pressure on each side of the valve, will be practically nil.

Probably the greatest difficulty will be the correct determination of the time when all the water in the sample is evaporated, and this will depend upon the efficiency of the diaphragm F in indicating small differences of pressure. The diaphragm can, however, be tested beforehand by subjecting each side to pressure by means of a column of mercury, noting what difference of pressure is required to break the electric circuit.

An error may be introduced, by the presence of air or vapors other than steam, in the sample. In all probability, however, if air were present it would be in exceedingly minute quantity and not sufficient to materially affect the result.

The apparatus may be applied to the receivers of an engine as well as to the steam pipe, and also to the exhaust as it leaves the low-pressure cylinder, by which means our knowledge of what goes on in the cylinders would be vastly increased.

In conclusion, the writer wishes to again emphasize the value of exhaustive trials on marine engines and boilers, so that some answer may be given to the following questions :

Is the economy of the triple-expansion engine due to high pressure alone, or due to lessened initial condensation in the cylinders owing to a diminished range of temperature? If so, why do trials show that the initial condensation in the high-pressure cylinder of the triple-expansion engine is just as much and sometimes more than the condensation in the high pressure cylinder of the compound engine?

Is there not reason to believe that the ordinary marine boiler supplies steam containing a hitherto unsuspected amount of water, thus accounting for the appprently large amount of condensation in the cylinder? Does the presence of water impair, *per se*, the efficiency of steam?

Is the amount of priming affected by the boiler pressure? Are steam jackets of any advantage to a marine engine, and if so, to which cylinder should they be applied?

ABOUT FEED WATER HEATING.

Editor CASSIER'S MAGAZINE :

DEAR SIR—In the last issue of your valuable magazine we note with considerable interest the article on the subject of feed water heating, by Mr. Albert Spies, M. E.

We were aware that the "Kirkaldy" system, as introduced in England, has shown as high as seven (7) per cent. saving in fuel, but we were under the impression that the "Weir" system, also referred to by Mr. Spies, and which takes steam from the intermediate receiver of the engine for heating the feed water, had shown better than four (4) per cent. saving in fuel. Both of these systems you perhaps know were tried years ago in this country before they were developed abroad.

With the "Peck-Wheeler" system, which we are introducing, we have obtained over twice as much economy in fuel as the first above named, and raised the feed water to over 300 degrees Fahrenheit. This system can be seen in operation at our works, Carteret, N. J., where we are saving over 1000 pounds of coal per day. Besides relieving the firemen from hard stoking, our grate bars last twice as long, and the boiler is relieved from the strains incidental to the old method of feeding boiler.

Mr. Spies's article is a very valuable addition to the discussion of this important subject, for he shows clearly the reason why the use of live steam taken directly from the boiler can be used to advantage—much as it may seem, on first thought, to be an impossibility. Where we combine the exhaust and live steam methods, as in the special arrangement of the "Peck-Wheeler" system, we get results never before obtained.

Wheeler Condenser and Engineering Company.

THE LIFE AND INVENTIONS OF EDISON.*

By A. and W. K. L. Dickson.

Seventh Paper.

THE phonograph from a commercial standpoint has shown remarkable signs of virility. In 1878, a company was formed, with a capital of $600,000 and having for stockholders the following influential men: Gardner C. Hubbard, G. L. Broadley, of Cambridge, Mass.; Charles A. Cheever, Hilborne L. Roosevelt, of New York; N. H. Painter, of Washington, D. C.; E. H. Johnson and T. A. Edison. The company, after organization, paid Edison a royalty of $10,000 as a guarantee of good faith, and agreed further to pay him twenty per cent. on gross receipts from all sources.

The Microscopic Company, of London, outstripped its numerous competitors in securing the use of the phonograph on British soil, and acquired that privilege for the sum of £1500 sterling, as a guarantee of good faith, in advance of a stipulated royalty. Mr. Edison's interests were similarly protected in Russia and France and other European countries, and an unusually solid pecuniary basis supported the fabric of international approval.

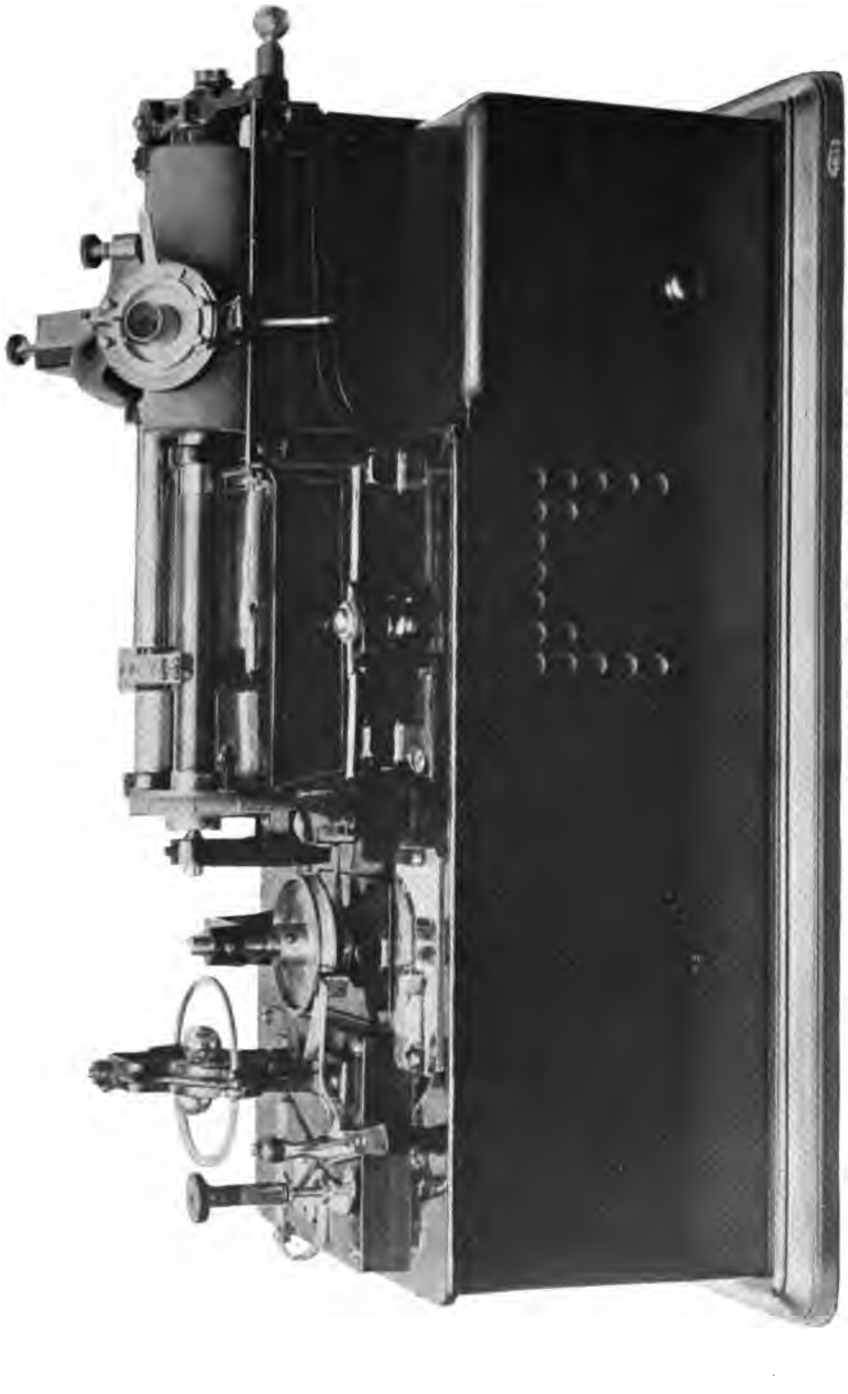
To-day the phonographic industries are represented by agencies in thirty-four States and Territories, and the central focusing point of supply, the North American Phonograph Company's headquarters in New York, ranks among the most stately and complete edifices in the great metropolis, while the Edison Phonograph Works, of Orange, N. J., located conveniently near Edison's laboratory, but operating under independent auspices, are marvels of concentrated energy.

These consist of four large buildings, each about 350 feet long. The main building or machine shop presents an immense vista of these appliances, such as drilling and cutting machines, planers, lathes, etc., all utilized in the construction of the 418 parts, which this complicated, yet simple appearing apparatus involves. The operations of japanning, polishing, nickel-plating, etc., are performed in specially assigned departments, after which the various sections are carried to the assembling room, carefully examined, put together, and placed in the stockroom, preparatory to packing and shipment, the latter work being greatly facilitated by the position of the Erie Railroad, which runs a branch of its cars directly to the door. In the sapphire department, probably the most interesting feature of the establishment, is found the perfected results of Mr. Edison's researches for materials in connection with the recorder stylus, turning-off knife and reproducer ball, all essential elements in the recording and reproducing parts of the speaking mechanism. The operations of shaping, grinding and polishing the rough stone are attended with extreme difficulty, and necessitate conscientiousness and expert skill. The sapphire is first sawed into thin slices, one-twentieth of an inch in thickness, then into cube pieces. In the production of the recorder stylus and reproducer ball it

* Began in November issue.

PHOTO BY W. K. L. DICKSON.

PHONOGRAPH ROOM IN EDISON'S LABORATORY AT ORANGE.



THE PATENT PERFECTED PHONOGRAPH.

goes through an additional process of concentration and grinding, receiving its final polish through the medium of very fine diamond powder, supplied through a wooden or shell cap. The operation is so exacting as to necessitate not only the most delicate manipulation, but the enlarging power of a strong microscope. Of extreme difficulty also is the formation of the reproducer ball, the primary shaping of which is done by a diamond tool, after which a special machine gives it the block, and the flat sides polished a nd ground, the final polish being imparted by machinery, which secures the required keenness of edge.

In the cylinder department an inquisitorial secresy prevails, and the component properties of the wax are locked in the bosom of one trusty familiar. Four weeks are required for the molding and seasoning of these cylinders, after which they are prepared for shipment.

Mr. Edison has perfected a method

SOMETHING FUNNY.

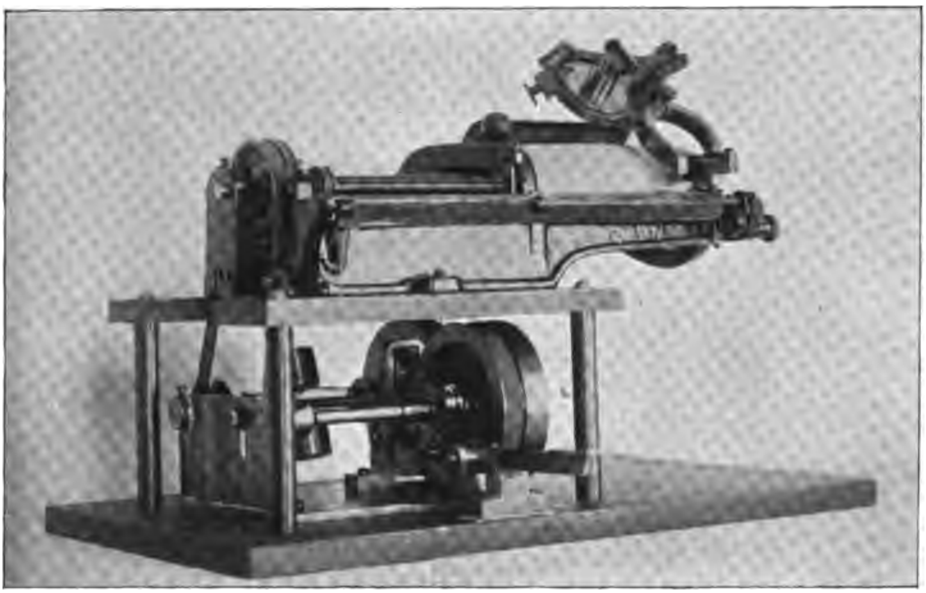
required spherical outline. This when completed is twenty-five thousandths of an inch in diameter. The cylinder upon which any record has been made may be again and again utilized. In fact the depth of the impression made by the human voice or a full brass band is so slight that thirty or forty records may be successively placed on the wax cylinders. For this purpose to each phonograph is attached what is called a turning-off knife. In the preparation of these turning-off knives, about sixty pieces are secured by cement to one

for the multiplication ot records—an important point where the golden tones of a Patti are in question, but as the minutiæ of these operations are held under the Rose, we will not touch on them further than to say that the cost of reproduction is trifling, and the process easy and rapid. To secure the first record is a matter necessitating expert skill, but once secured, an indefinite number of fac-similes may be obtained from the original cylinder. In fact, no experiments have succeeded in establishing the limits of this repro-

ductive power. Its durability is something marvelous. Time seems to have no effect in injuring its component properties. Legal deeds may therefore be safely incarcerated during a period of possibly a hundred years, and disinterred whenever the majestic deliberation of the law sees fit to require their presence.

The complex schemes of the Phonograph Works are admirably administered by the superintendent, Mr. Geo. F. Ballou, whose exceptional skill in intricate mechanism, especially fits him for the post. Mr. Ballou's efforts are most efficiently supplemented by the office manager, Mr. Hamilton Miller, under whose charge is placed the vast bulk of official records and correspondence. As the former department involves a minute technical acquaintance with every branch of phonographic industry, and as the latter includes an enormous amount of irrelevant matter, couched in every imaginable tongue, and representing every tinge of mentality, sane and insane, the varied scope of Mr. Miller's duties may be realized.

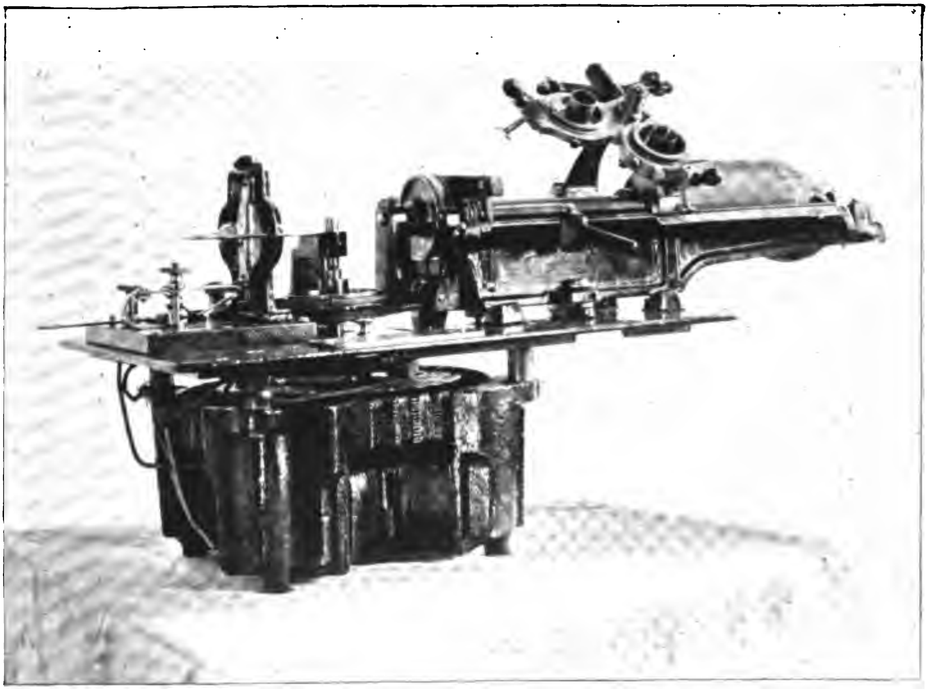
The phonograph, in its several stages of development, for no child of Edison's brain has ever received such fostering care, has been the focussing point of interest in every exhibition which has taken place since 1878, and it has been the recipient of eulogistic notices, sufficient to disturb the equilibrium of even so well balanced and precocious an infant. No medals have been directly awarded to the phonograph, simply because there has been no competition on that score, but the majority of the distinctions conferred upon Mr. Edison have been called forth by this unique production of his genius. In the French Exposition of 1889, the perfected phonograph furnished a pacific meeting-ground for the most antagonistic types, and no nationality, from the impassive Turk to the excitable Gaul, could resist the temptation of hearing its tones reproduced. "Never before was such a collection of the languages of the whole world made. It was the first linguistic concourse since Babel times."



PHONOGRAPH OPERATED BY WATER MOTOR.

Mr. W. J. Hammer, who was in

charge of the phonograph department at the Exhibition, estimates the daily concourse of people attracted by that instrument alone at 30,000. Forty-five phonographs were used, most of them being shown in the machine gallery, where the major part of Mr. Edison's display was situated, and the balance in the special phonograph pavilion, constructed at great expense in the industrial section. The public was afforded every facility for the registration of tone, and an endless variety of effects were secured, including a faithful reproduction of the Eiffel cannon, and embracing contributions from the most distinguished electricians, musicians and statesmen of Europe. Amongst the visitors present were President Carnot and his family, Mr. and Mrs. Gladstone, the Prince and Princess of Wales, the Prince of Monaco, Buffalo Bill and suite, and De Brazza, the famous African explorer. De Brazza brought with him about fifteen representatives of different African tribes, all of whose various inflexions of sounds were carefully embalmed. The explorer showed deep interest in the phonograph, and looked hopefully to the time when that instrument would serve an important use in South Africa. Four or five of the tribes represented had no written alphabet, and the various trading companies and governments who desired to make contracts with the natives were at their wits' ends to discover methods of recording these treaties. By means of the phonograph, an official record could be made of the conversations, and a wholesome check imposed on the slippery imagination of the contractors.



PHONOGRAPH AND ELECTRIC MOTOR.

Amongst the triumphs achieved by the phonograph may be reckoned the utter annihilation of Indian composure. One of the Sioux braves, composing the suite of Buffalo Bill, was requested

EDISON'S PHONO-MOTOR OPERATING SEWING MACHINE.

to step forward and speak into the phonograph, which he did, with no relaxation of his constitutional dignity, but the matter was otherwise when the garnered accents found their way back to the auditory nerves of Red Shirt, the famous chief. On hearing the familiar gutturals, he became terrified, threw the tubes down and jumped backward several paces, his face and manner indicating the greatest alarm, nor could he be prevailed upon to again approach the instrument, insisting that he had heard the voice of the Great Spirit. After this mysterious manifestation of power, the Indians would not come nearer than fifteen or twenty feet of the phonograph, and seemed to regard it with a superstitious awe.

Within the line of thought, suggested by the phonograph, came the phonomotor, an instrument for measuring the mechanical force of sound waves, and warranted to accomplish the occult feat of "talking a hole through a board," a consummation most devoutly *not* to be desired. The diaphragm and mouthpiece are similar to those utilized in the phonograph, and secured to the centre of these is a brass rod carrying a steel pawl, the latter actuating a ratchet wheel, furnished with a series of very sharp teeth, mounted on a delicately centred shaft with flywheel attached, and impelling forward a colored disc, by means of a belt. The flywheel is swift to catch the infection of the sounds communicated to the diaphragm by the tones of the human voice, and responds to the call with a velocity which is amazing. If sounds involving any degree of continuity are employed, the

TELEGRAPHING FROM A PULLMAN PARLOR CAR ON TRAIN IN MOTION.

flywheel revolves with such speed as to necessitate considerable force in bringing it to a standstill. A new field is opened up for those "sophistical rhetoricians, inebriated with the exuberance of their own verbosity," to whom garrulity is as the very breath of life. As shown in the illustration, the seamstress may exercise her vocal powers instead of the treadle, the tirades of a virago may find expression in a pile of neatly sliced kindling, while the nineteenthlies of her reverend spouse, may receive ultimation in the sawing of sub-

stantial logs. Thus shall the law of compensation be made good, and the clouds of suffering, induced by strident tones, be lined with the argent of domestic economy. From this fruitful source of discord, human speech, we pass in orderly sequence to one of Edison's inventions, a strange field of thought for a mind devoted so exclusively to the promotion of placid industries. This is none other than the Edison-Simms torpedo, a formidable engine of destruction, consisting of a submarine torpedo boat, propelled by electricity. The torpedo proper furnishes an encasement for the explosive charge and the electrical motor, and being lowered several feet under water in a float, is controlled from a neighboring ship, or from the shore, by means of an electric cable, through the medium of which all currents for the regulation of speed and direction are transmitted.

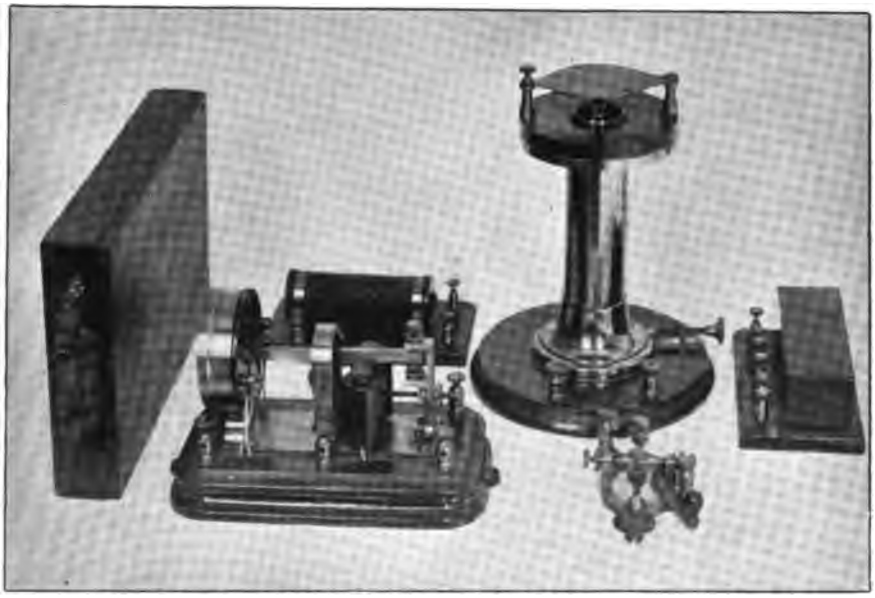
Faster and faster, as the years flew on, came the marvelous inventions. Thick as owls in Athenian temples, they crowd about us, supplying an emphatic denial to those moldy aphorisms which deal with the impossibility of heating more irons than one, and which cast such serious imputations on the trading abilities of our nursery friend, James. The prolific field of telegraphy yielded new and perfected forms, with every succeeding month. The Harmonic Multiplex Telegraph was devised, consisting of a number of tuning forks or reeds, of varying size or pitch, placed at each end of the line, in exactly corresponding pairs, each one independently energized by electro-magnets, the reeds becoming both key and sounder. Each receiving reed or tuning fork responds harmonically only to its own pitch or number of vibrations per second, so that a large number of reeds can be used, or messages sent over a single wire through the medium of the ordinary Morse code, without necessarily interfering with each other. Mr. Edison has sent as many as sixteen messages at a time, or eight each way.

Perhaps one of the most interesting of these devices is that known as: "Telegraphing from a moving train." In this ingenious application no extra wire is utilized, and the viewless air alone officiates as a medium in the transference of the electrical currents from the train apparatus to the ordinary telegraph wires running alongside the track. Induction, or that wonderful property of the science by which electricity may be developed in a substance by the influence of neighboring electricity, is the underlying force employed, and explains the fact that the currents induced are enabled to circulate without the smallest hindrance to their legitimate uses. An ordinary battery, a couple of telephone receivers, an induction coil with vibrator, and a Morse key, constitute the details of the apparatus. The induction coil transmutes the current from the battery into one of swiftest alternating properties, which produces a like current in neighboring wires. The humming sound called forth is changed, through the medium of the key, into the familiar dots and dashes of the Morse system. The roofs of the cars are rendered available by the attachment of wires, connected with each other and with the instruments, which in their turn are linked with Mother Earth, through the car wheels and track. The workings of the system have been so feasible and inexpensive that train telegraphy has passed into extensive use, and messages have been sent over an aerial space of five hundred feet, the distance between the wires and cars. Its proven ability in the prevention of those blood-curdling accidents incident to travel, and its success in the interception of criminals and the promotion of social comfort, have rendered it an indispensable adjunct to railroads. Mr. Edison, moreover, anticipates a further application of these principles to marine service, in which case balloons, kites, and foil-covered sails will take the place of the train roofs, and will be secured to the apparatus on board.

The phonoplex is in the same line of thought as the duplex telegraph, and occupies a middle ground between telegraphy and telephony. An ex-

cellent feature of this system, and one which should enlist the respect of all familiar with our climatic vagaries, is its ability to work in evil weather, and under conditions which render the Morse system impracticable, from the leakage along the line.

From the borderland, presented by the phonoplex, we pass to the thickly populated regions of telephony, than which no region of electrical science has been more extensively and successfully exploited. In this department we find such a multiplicity of forms, that no manual, however ponderous and verbose, could hope to exhaust the theme. The water telephone, chemical telephone, electrostatic telephone, inertia telephone, mercury telephone, voltaic pile telephone and musical transmitters, are simply specimens of Mr. Edison's varied achievements in this line.

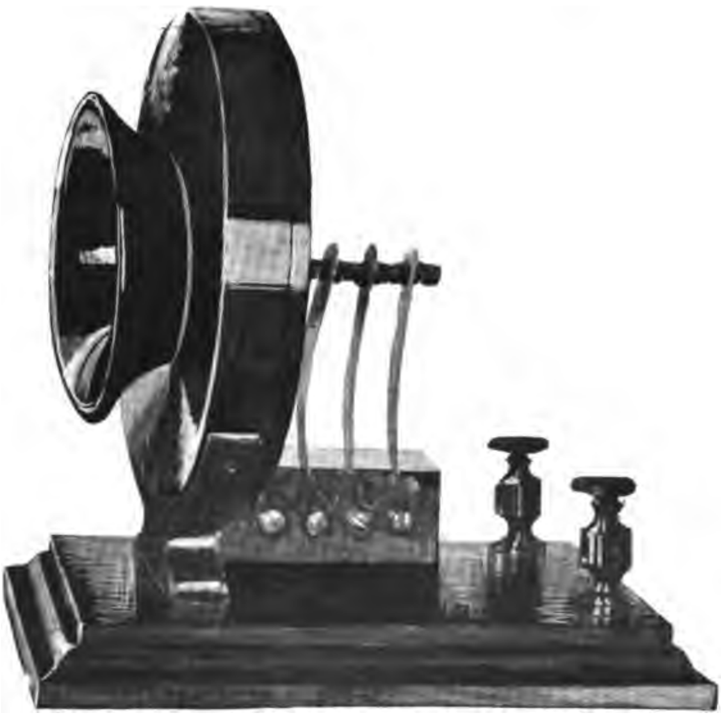


EDISON'S PHONOPLEX SYSTEM OF TELEGRAPHY.

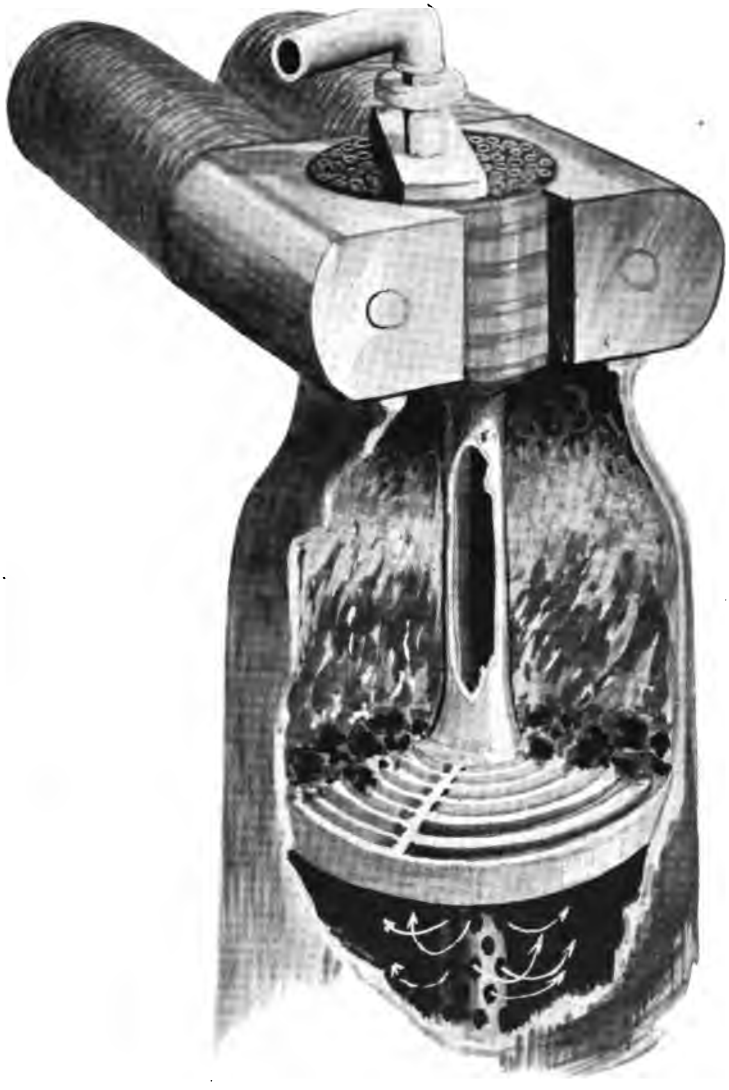
Every grade of employment and every requirement of existence come within the range of this flexile invention, and are met in public life by what every one knows as the telephone exchange, a system by which the central office is connected by electric wires to the subscriber's house or place of business, each man being supplied with an individual wire and an accurate list of his fellow-subscribers, any one of whom he may communicate with, through the medium of the central office, and without the necessity of quitting his own comfortable quarters. The time, trouble, and expense saved, are something incalculable, and offer a striking contrast to former methods, which were wont to render the "calling up" of a fellow citizen about as delicate a task as the mystic offices of Endor's witch. "Why hast thou disquieted me to bring me up?" must often have been the feeling interrogatory of a fellow civilian, after one of these fatiguing and fruitless interviews. The superiority of the new methods is vindicated by the astonishing growth and multiplication of the telephonic exchanges on both sides of the Atlantic,—New York city alone numbering several thousand subscribers.

This is an age of progress, and these methods, immeasurably superior as they are to their predecessors, may possibly yield to the simpler conditions of what is known as the "Stowger system of Telephone Exchange," in which the presence of that charmer, airily alluded to by Mark Twain as "Hello, Central"—is replaced by a small but apparently complicated contrivance, immured under a glass case. When the subscriber wishes to call up any one, he proceeds to make up, upon four keys, the proper numerical combination, after which, on depressing a fifth key, he is duly connected, provided always the line be free. If it is not, the number called for will not appear in the space reserved for it above his telephone.

The microphone bears a family resemblance to the telephone, with this important difference, that it magnifies the sound in the process of transmission. In the development of this mechanism Mr. Edison embodied the truth that if carbon varies in electrical resistance with variation in pressure, this variation must be heightened to an indefinite degree if the carbon be permitted to make a loose contact with its partners in the electrical circuit. This principle receives extensive application in all microphones used in connection with telephony. Struck by the increased loudness of the sounds, resulting from the multiplication of contacts, and the consequent exaggeration of the variations in resistance, Mr. Edison was led to the construction of a microphone having a number of upright carbon pieces, each supported by a light spring. To the diaphragm is attached a carbon button, our old Protean friend, against which the first carbon rests, and the vibrations in the diaphragm are passed successively from carbon one to carbon two, and so on, with the result of heightening to a mar-



EDISON'S FIRST MICROPHONE TRANSMITTER.



INTERIOR VIEW OF EDISON'S PYRO-MAGNETIC MOTOR—HEATED BY COAL.

velous degree the sounds communicated to the telephone receiver.

In the evolution of the microphone, Mr. Edison was confronted by a formidable antagonist in the person of Professor Hughes, and many choice flowers of rhetoric found their way into the daily papers. The honors of the field remained eventually with Edison, but the pretensions of his rival are amongst the few circumstances connected with his scientific career which have succeeded in ruffling the serene tides of his philosophical nature. "One of the biggest steals ever made," was Edison's vigorous remark at the time, "filched directly from my telephone."

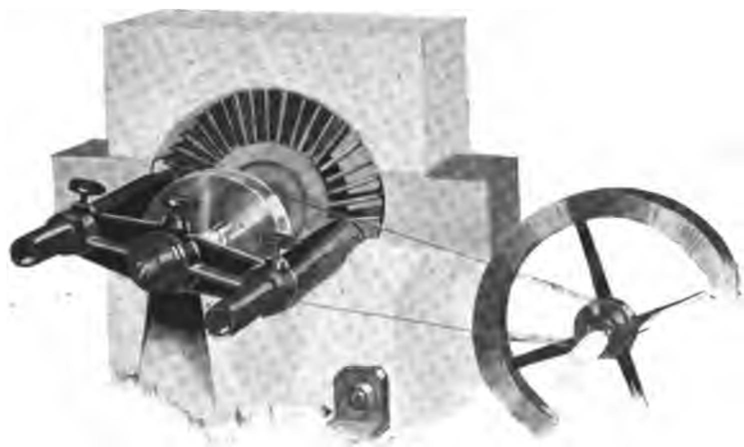
An abnormal degree of credulity is required to appreciate the capabilities of the microphone. The passage of a delicate camel's hair brush was mag-

nified into an impetuous roar, resembling the progress of a mighty wind through the resonant foliage of giant pines; a tiny gnat, on "light, fantastic toe," gave forth a sound like the tramping of Rôman cohorts; while such infinitesimal sounds as the ticking of a watch and the pulsations of the heart, were distinctly audible through a distance representing 100 miles of space. Instances might be indefinitely multiplied, but these are sufficient for the purpose of demonstration.

In the line of magnetic experiments, the pyro-magnetic motor and pyro-magnetic generator are interesting, as to exert any influence on the red hot metal. Edison gave a material encasement to this ghost of primitive science by the creation of the pyro-magnetic motor, a machine in which a pivoted bar is heated and cooled, by turns, being attracted toward the electric magnet when cold, and left uninfluenced while hot, the alternation producing the rotary motion.

The pyro-magnetic generator is based on substantially the same principles, with the end in view of producing electricity, directly from coal.

"To do this," remarked Mr. Edison, "has long occupied the close attention

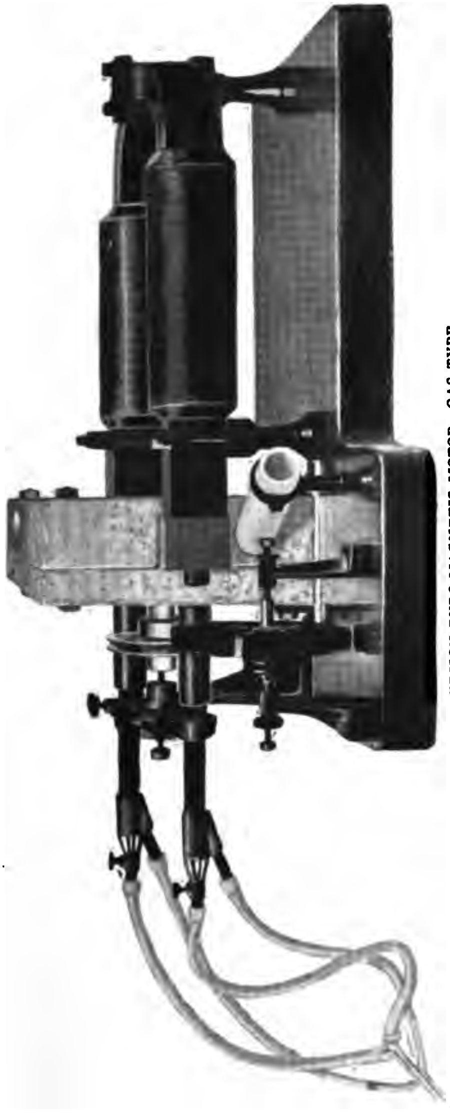


FRONT VIEW OF EDISON PYRO-MAGNETIC MOTOR—GAS TYPE.

reviving an ancient principle, discovered by a learned physician, at the court of the virgin queen, Sir William Gilbert. This wise man, whose important and well digested contributions to electrical science have earned for him the title of the first electrician, and whose attainments moved the envy of the illustrious Galileo, published a work in 1600, entitled "*De arte Magnetica*," which has recently been translated and published by John Wiley & Sons, of New York. It is remarkable for its systematic and inductive thought, and demonstrates the diminution of magnetic power in iron, under conditions of extreme heat, the magnet failing of investigators. Could the enormous energy, latent in coal, be made to appear as electric energy, with remarkable economy, the mechanical methods of the entire world would be revolutionized and another great step of progress would be taken."

To the reformer of the future, this concentration of domestic forces is warmly recommended. Imagine a household in which the entire illumination, heating and culinary operations find their origin in one common source of energy, and that, an ordinary and unpretentious coal stove! Truly the appliance has risen in the social scale since those days when Dickens took

such virulent exception to their existence. According to that highly imaginative writer, no American establishment, floating or stationary, could be complete without "the everlasting



EDISON PYRO-MAGNETIC MOTOR—GAS TYPE.

stove in the midst, hot, suffocating and vaporous as a witch's cauldron." We confess to a fellow feeling for that transatlantic wail, whenever memory reverts to our ostracised grates and hearths, but our attitude toward that national abomination will be materially softened, if, as Mr. Edison claims, it can alleviate, in any degree, the crushing burden of domestic misery.

The magnetic bridge may also be briefly mentioned. It is an application of the principles embodied in the Wheatstone Bridge, and its purpose is directed toward testing the quality of the iron, entering into the construction of dynamos, and detecting flaws in that metal or in steel.

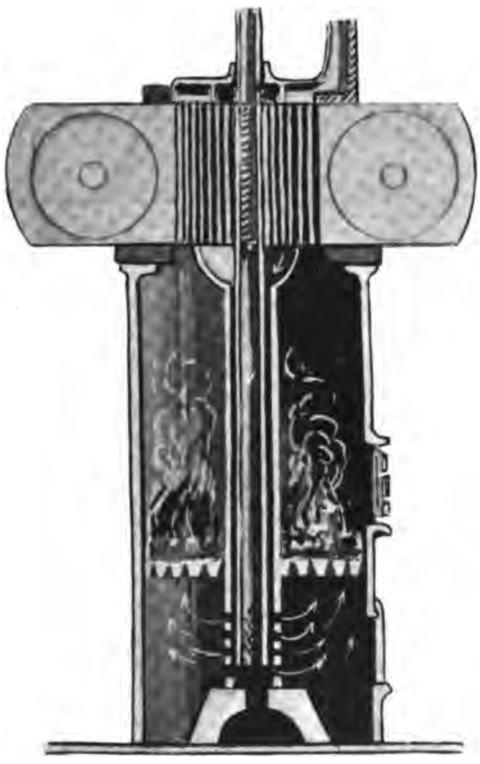
Electric railroading was amongst the earliest branches of locomotive science investigated by Mr. Edison, and in this, as into the dryest of his projects, his characteristic humor found play. On one occasion, he conceived the brilliant idea of constructing what he termed a "Mountain Climbing Electric Railroad for South America." With these lofty aspirations in view, he built a track on on a down hill grade at an angle of forty degrees, using grippers to catch the rail and ensure a modicum of safety. His experiments in this line received a check one day through the sudden breakage of the grippers, in consequence of which the car rushed down the hill with tremendous velocity, and, to use Edison's turn of phrase, well-nigh pitched the solitary passenger, a small and adventurous boy, "over into the next county."

This was a wild tangent, however, from the sane and legitimate line of electric railroading, which found its basis at Menlo Park, and which was exploited with considerable success in after years. In the earlier stages of this enterprise, Edison invited the directors and shareholders of the road to a trial trip, an invitation which, being couched in irreproachable terms, was accepted with bland and unsuspicious politeness. After the interchange of the usual amenities, the dignitaries took their seats, expecting naturally a decorous exposition of the new system, spiced by appropriate and improving conversation, but alas! the irreproachable bearing of these reverend *signores*, far from inspiring respect, aroused the demon of ribald mirth in Edison's degenerate breast. Without the slightest

intimation of his purpose, he turned the motive power on full force, and dashed his living freight along at the rate of about forty miles an hour, increasing the speed in proportion to the growing discomfort of his guests. Faster and faster flew the pliant engine, higher and higher rose the terror of the directors, hats floated on the breeze, coat-tails flapped, and frenzied protests clove the air, but Edison, school-boy fashion, was only stimulated into fresh depravity by the agony of his victims, and spared them no pang that his ingenuity could devise.

The railroad was a pet scheme of Mr. Edison's. The current was furnished from the laboratory, passing into the rails, which were pitched for insulation from the ground. Entering through the one rail, the current passed up through the wheels, which were also insulated from the shaft, thence to the motor, and out through the other wheel. The electro-motive force, employed at that time, was one hundred and twenty-five volts, and the motor was simply one of Mr. Edison's dynamos, afterwards known as type Z, or sixty-light dynamos.

Shortly after the inauguration of the Menlo Park scheme, Edison found himself confronted by two formidable rivals in electric locomotion, Messrs. Siemens and Field. The claims of the former were dismissed by the court, and a consolidation was effected with the latter, which resulted in the establishment of the Electric Railway Company of the United States. Immediately upon this comfortable adjustment of affairs came the opening of the Chicago Exposition in 1883, and it was determined, despite the paucity of time, materials and ac-



SECTIONAL VIEW EDISON PYRO-MAGNETIC MOTOR.

commodation, to indulge the public with a taste of the new project. The enterprise was the outcome of Messrs. Field and Edison's genius, but so serious were the obstacles encountered, that the exhibit can hardly be said to furnish a just exponent of their methods. Still, the experiment was attended with a large measure of popular success, and derives interest from the fact of its being the first electric railroad, based upon business principles, which has been in-

EDISON PYRO-MAGNETIC GENERATOR. OPERATED FROM ORDINARY COAL STOVE.

troduced into this country. The locomotive, which received the cognomen of "The Judge," in honor of the designer's uncle, Chief Justice Field, was five feet wide by twelve in length, and weighed in the neighborhood of three tons. A "throttle valve," very similar to the arrangements for the regulation of speed now existing on American railroads, enabled the engineer to control the electric force at his command, and to slacken or accelerate at will. He also controlled an apparatus for the reversal of the current and the backing of the locomotive, and was provided with an electric bell, having a resistance of three hundred ohms, which served as a safeguard against the diversion of the current from the motor.

The track was laid in the gallery of the main exhibition building, extending along the sides, and curving abruptly at either end, with a radius of sixty-five feet, the entire length covered being about one-third of a mile and comprising three rails, the central one utilized for conveying the current, the two outer ones securing its return. The original project had looked to a maximum speed of twelve miles an hour and the running of two passenger cars, but these ambitious designs were perforce modified to meet the enfeebled constitution of the gallery, which resented the imposition of increased weight and impetus by the most alarming symptoms of collapse. It was therefore deemed imprudent to exceed nine miles an hour, but the defective rate of progress was counteracted by that delicious sense of peril, which is amongst the many incongruities of our chaotic nature.

"The Judge" covered himself with glory, and proved more than a nine days' wonder. During the thirteen days of its operations, it carried a total of 28,805 passengers, and accomplished 1588 trips. The high water mark of popular patronage was reached on the closing day of its exhibition, Saturday, June 23, when 194 trips were made, and 3580 people transported, in more senses than one. After its successful debut at Chicago, "The Judge" was despatched to the Louisville Exposition, where an electric railway had been prepared for his accommodation, and where a reception was accorded him, in keeping with his judicial rank. Mr. Edison has continued his experiments in this line, but not with the full concentration of his intellect, his powers having mainly directed toward the fruition of the phonograph, the electric light and the telephonic and telegraphic systems. He has not abandoned the idea, however, as a brisk and extensive electric

locomotion testifies, and he anticipates a time when we shall be flashed through space at the rate of fully one hundred miles an hour; a speed invaluable to business men, but hardly compatible with a lingering contemplation of the landscape.

Much excellent work was also accomplished by Mr. Edison in the line of galvanometers, amongst which the dead beat galvanometer marks a new departure, differing from other instruments in its ability to dispense with the usual coils and magnetic needles. Its operation is dependent on the heating of the current, which causes the expansion of a delicate platinum-irridium wire, encased in a tube of glass. This expansion sets a coiled spring in motion and causes it to act upon a pivotal shaft, to which is attached an exceedingly small mirror, the desired indications being furnished by the projection of the light rays upon the scale. The title of the instrument is a suggestive one. Let us hope that it is not based on Mr. Edison's sensations in the process of investigation.

About this time, 1883, the electric pen or autographic press, an instrument intended for the multiplication of documents, pictures, etc., became the subject of Edison's diversified genius, and being subjected to a hot-house process of fruition, soon made its appearance in the commercial world, where its rapidity and inexpensiveness brought it into extensive demand. The results attained by this ingenious instrument were practically those afforded by lithography, with the advantage of being so easily manipulated as to be independent of expert skill. It is shaped like an ordinary pen-holder, hollowed out to receive a needle-pointed steel shaft, which is driven up and down at a high speed by a small eight motor, attached to the top of the holder, from which a flexible cord passes to the battery.

The primary operations of the penman result in a series of very fine punctures, which are distinctly visible when subjected to the transmitted light. A sheet of fresh paper is placed under the perforated page, and an ink roller, saturated with ink, is passed over the punctures, with the result of securing an exact reproduction of the original, not, as might be supposed, by a series of dots, but in a continuous line. This latter and somewhat curious phenomenon is due to the exceedingly close proximity of the holes.

A writer gifted with a humorous turn of mind remarked that "if the intelligent public would imagine the 'business end' of an irate wasp, suspended

EDISON'S MAGNETIC BRIDGE.

EDISON'S ELECTRIC PEN.

between the operator's thumb and finger, and venting its pent-up feelings by stinging a succession of holes through a sheet of paper, some idea might be gained of the electric pen and its workings."

Little impetus was required to set the delicately poised brain of the inventor in motion, and it is said that the first idea of the electric pen originated in the remark of a friend and prominent merchant relative to the restrictions of ordinary caligraphy: "Why in creation, Edison," said this much-tried individual, "don't you turn your attention to inventing something that would save this endless waste of time and labor?" This cursory hint was sufficient for the scientist's alert mind, and the electric pen was the result.

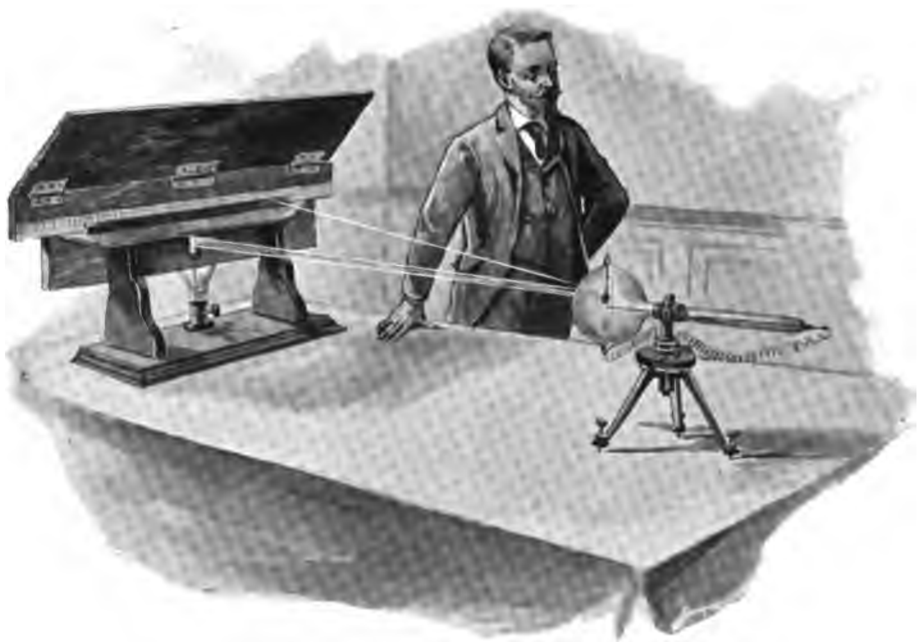
A modification of the electric pen, the mimeograph, followed almost immediately upon its production, and being of simpler construction and based upon more economical principles, it speedily secured the approbation of that feverish portion of the public to whom time means money.

A sheet of thin waxed paper is placed over a steel plate, roughened like a very fine file, and presenting a surface of very sharp points. By writing on the prepared paper with a smooth, steel-pointed tool on stylus, perforations may be made, almost identical with the ones accomplished by the electrical pen, the process of duplication by means of the ink-roller being the same. As many as two thousand copies from one writing have been secured by these methods, all finely toned and exquisitely legible, while the saving of time, strength and expenditure are so marked as to constitute an era even in this age of commercial and literary compactness. Used in connection with the typewriter, a recent and highly effective partnership, the manifold reproduction of matter is secured by means of a sheet of prepared stencil paper, used with a perforating silk, in place of the ordinary ribbon.

From the standpoint of romance and picturesqueness, the electric pen and mimeograph, with their commonplace exterior and undignified celerity, contrast unfavorably with the splendor and stately deliberation of ancient methods; but this is essentially a utilitarian age, and it behooves us, with what grace we can, to accept the inevitable. Yet a love of beauty is inborn in the human breast, and on those rare occasions when "Reason, that valiant Captayne of ye sowle," lies at ease within the poppied gates of sleep, the vagrant faculties are very apt to play truant and seek entrance to the tempting and illogical playgrounds of the Past. Then does the mind, released from that grim thraldom, revert with loving tenacity to the glowing pictures which stud the pages of history.

Assyrian despots, scintillating with gems, and robed in cunning needle work, bending their swart brows over cylinders of terra cotta, or grinding their heavy, triangular implement over a surface of moistened clay, in the wedge shaped signs, so characteristic of the invincible sons of Ashur!

Stern visaged Egyptian rulers, enthroned amid vistas of solemn colossi, and entrenched in an inscrutable calm, which borrowed no warmth from the mellow radiance of the setting sun! Seti the wise, Hatasu the arrogant, Rameses the divinely beautiful,—inscribing their inflexible decrees on scrolls of Nile-born papyrus, while the swelling chorus echoed through the illimitable courts.



EDISON DEAD BEAT GALVANOMETER.

> "Work, my brother, while 'tis day—
> Pharaoh lives forever!
> Rivers waste and wane away,
> Marble crumbles down like clay,
> Nations dwindle to decay;
> But Pharaoh lives forever!"

Toged and fibulæd exquisites, votaries of Tibullus and Anacreon, their scented locks bathed in dews which never owned Parnassus, registering their ephemeral vows on tablets of virgin wax, and compelled to many eras-

ures, through the reversal of the stylus by the restrictions of an intellect made inert by deep draughts of spiced Falernian!

Kings of the Scandinavian seas, azure mantled and wing helmeted, clad in mail of precious metals, demi-gods in stature and in comeliness, cutting the Runic symbols at point of battle sword through the fragrant fibres of birch bark and pine, the while the great war dragons chafe at their hempen gyves, and voice of northern wind and thunder of ocean surges unite in a wild pæan of impending victory!

Dim oratories in mediæval cloisters, lit by casements

> "high and triple arched,
> All garlanded with carven imageries
> And diamonded with panes of quaint device,
> Innumerable of stains and splendid dyes,
> As are the tiger moth's deep damasked wings;"

pale monks, on whose wasted hands and sunken temples "rose bloom and softest amethyst" fall unheeded, and from whose hearts the chapel harmonies, "yearning like a God in pain," evoke only a dim sense of loss,—inscribing with anxious care on sheets of pearly vellum, the jeweled characters, destined to illuminate the darkened hearts and minds of mediæval life!

Alas for!—

> "The classic days, the mothers of romance,
> That roused a nation for a woman's glance;
> The age of mystery with its hoarded power,
> That girt the tyrant in his storied tower,
> Have passed and faded like a dream of youth,
> And riper eras ask for history's truth."

(*To be continued.*)

LEADING AMERICAN ENGINEERS.—ROBERT W. HUNT.

ONE of the leading American engineers who is almost as well known abroad as in America is Robert Woolston Hunt, whose portrait is printed on another page.

Mr. Hunt was born in Fallsington, Bucks county, Pa., December 9, 1838. His father, Doctor Robert A. Hunt, a graduate of Princeton College and the University of Pennsylvania, was a successful practicing physician, and was of the Trenton, N. J., branch of the Hunt family, while his mother, Martha Lancaster Woolston, was of a well known Quaker family of Pennsylvania. Owing to failing health, Doctor Hunt gave up his practice and moved to Covington, Ky., where he died in 1855, leaving his widow and only child, Robert, who had to assume a man's duties. After continuing his father's drug business for two years, impaired health compelled him to relinquish it. He moved to Pottsville, Pa., and after a short rest entered the iron rolling mill of John Burnish & Co., and devoted several years to acquiring by actual work a practical knowledge of puddling, heating, rolling and the other details of the iron business. In 1859, he entered the laboratory of Booth, Garrett & Reese, and took a course of analytical chemistry. Two years later, while employed by the Cambria Iron Company of Johnstown, Pa., as chemist, he established a laboratory at their works, which was the first in America operated as part of the organization of an iron or steel company.

In the spring of 1861, he assisted in starting the Elmira Rail Mill, at Elmira, N. Y. Later in the year at the breaking out of the Civil War he entered the United States military service and in the fall of 1862 was in command of Camp Curtin at Harrisburgh, Pa., with the rank of captain. In 1863 he served as mustering officer for the State of Pennsylvania with the same rank, and the following year he assisted

in recruiting Lambert's Independent Mounted Company, P. V., and was mustered in the United States service as a sergeant, having "tossed up" with a friend, it is said, as to which should take a lieutenant's commission. Upon being mustered out of service in the fall of 1864, he returned to the employ of the Cambria Iron Company and early in the following summer assumed charge of the experimental Bessemer Works at Wyandotte, Mich., of which the Cambria Company were part owners. He remained there for about a year, when the Cambria Iron Company called him back to Johnstown to take charge of their steel business. He assisted George Fritz, their chief engineer, in designing and building their Bessemer works, and assumed charge of it on its completion, July 10, 1871. Two years later he resigned his position, and in 1873 entered upon the duties of superintendent of the Bessemer works of John A. Griswold & Co., Troy, N. Y.

In March, 1875, he became general superintendent of the Albany and Rensselaer Iron and Steel Company, which had acquired these works as well as those of Erastus Corning & Co. This organization became later the Troy Steel and Iron Company. During the thirteen years he remained in charge, he almost completely rebuilt the various works of the company, and also erected a large blast furnace plant of the most complete character. Mr. Hunt has taken out several letters patent on steel and iron metallurgical processes and machinery; both individually and in conjunction with John E. Fry, William R. Jones, Dr. August Wendel and Max M. Suppes. The Hunt-Jones-Suppes rail mill feed tables are used under licenses by the majority of the rail mills in the United States. Mr. Hunt served three terms as commander of John A. Griswold Post, No. 338, G. A. R., of Troy, from which position he resigned, on removing from that city. On December 5th, 1866, he was married to Miss Eleanor Clark of Ecorse, Mich.

He has had a very prominent connection with American engineering societies, and in 1883 was president of the American Institute of Mining Engineers. At different times he has served in the Council of that institute, and on the board of managers of the American Society of Mechanical Engineers. He was elected president of the latter society in November, 1890. He is a member of the American Society of Civil Engineers and Western Society of Engineers, also a trustee of the Rensselaer Polytechnic Institute of Troy, N. Y. He has frequently contributed papers to the various scientific societies of which he is a member; and has lectured before the Franklin Institute of Philadelphia and the graduating classes of the Rensselaer Polytechnic Institute and Sibley College, Cornel University.

In April, 1889, he established the bureau of inspection, tests and consultation of Robert W. Hunt & Co., with principal offices in Chicago, Ill., to which city he removed in the spring of 1889, and the great success of his present work shows the value of the experience gained during his active life in iron and steel manufacture.

LUBRICATING CAR AXLES IN GERMANY.*

By Prof. J. E. Denton.

AT the request of the writer, Mr. F. T. Gause, during his location for some weeks in Hamburg, in connection with lubricating oil experiments for the Standard Oil Company, made the following notes regarding the most improved methods of lubricating car axles on German railways.

The fresh lubricating oil is fed to a reservoir at the top of the box, Fig. 1, and reaches the journal by wick syphon. A pad of elaborate construction, Fig. 2, is pressed against the lower surface ot the journal, and is kept saturated by capillary, or syphon action, from oil carried in the bottom of the box, Figs. 1 and 4. A felt ring, Fig. 3, fits snugly in an annular groove in the box, and is made to hug the axle closely by means

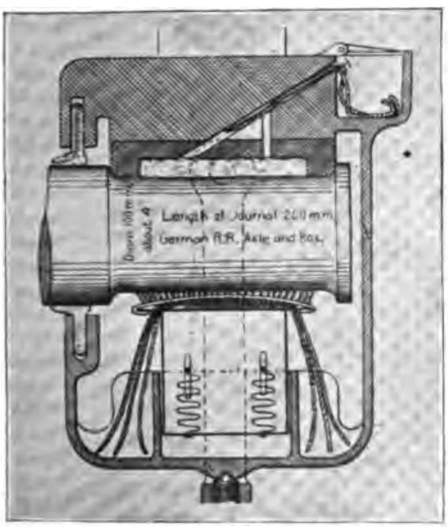


FIG. 1.

of two light brass spiral springs. This prevents the escape of oil from and the entrance of dust to the box.

The speed of trains ranges from fifty-six English miles per hour for passenger service to twenty-eight miles

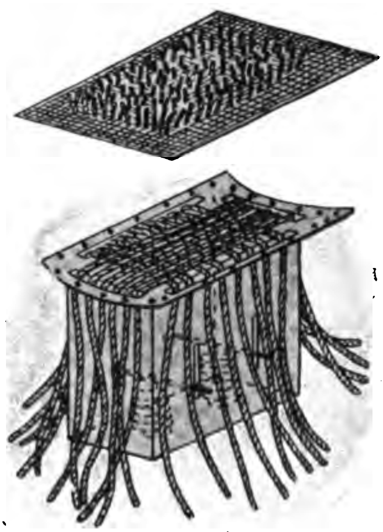


FIG. 2.

for freight service. The number of axles per passenger car varies from two to four.

Passenger trains of six cars, running 176 miles between Hamburg and Berlin, averaging a total of fifteen axles, use one-fourth of a pint of oil per axle per 100 miles. The pressure per square inch of projected area of bearings averages about 325 pounds, and the rubbing velocity about 400 feet per minute. The pressure per square inch, rubbing speed, and the quality of lubricating oil, are practically the same as are common to American passenger traffic, in which the oil is applied by saturating a loose mass of woolen or cotton waste, and a dust guard is used consisting of a disc of leather or wood. The average consumption of oil in American practice is

* Originally printed in Stevens Institute Indicator.

given by Hall's "Car Lubrication" as two-fifths of a pint per axle per 100 miles. The writer has noted, however,

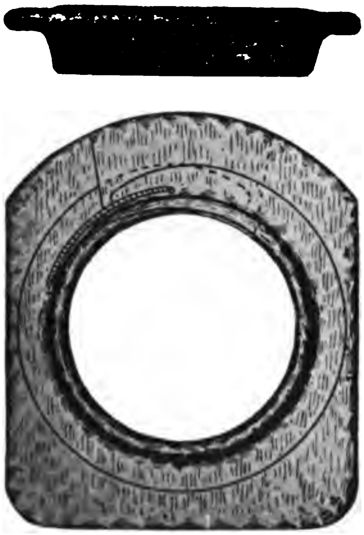


FIG. 3.

that first-class American passenger service consumes one pint per axle per 100 miles.

A much lower rate of oil consumption has been reported for the European "pad feed" box, than is given by Mr. Gause. For example, Wellington, in his "Economic Theory of Railway Location," quotes a consumption of one-seventieth of a pint per axle per 100 miles. Such results do not, however, represent the average consumption, but rather possibilities, when special care is used to limit the consumption by following a car for a test with bearings in the best condition. Under such conditions the use of woolen waste has permitted the consumption to be as low as one-tenth of a pint per axle per 100 miles. There is no doubt that the use of a "pad" instead of waste, and of a more elaborate dust guard, may reduce the average consumption to one-fourth that common with waste, but the greater care necessary to maintain

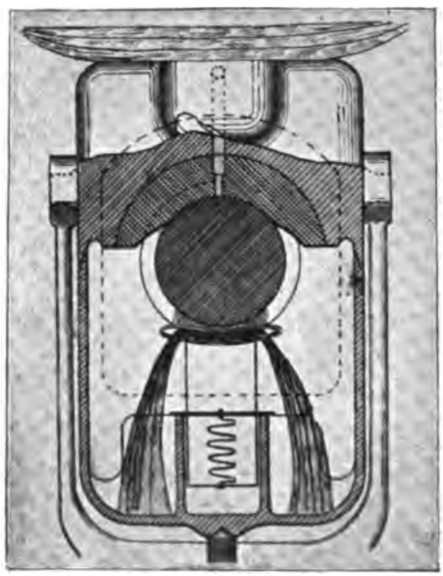


FIG. 4.

springs and syphons, in good working order, has thus far made the use of waste preferable in American practice.

BLUE PRINTING.

By Joseph P. Geiger.

EVERY reader of this magazine knows what a blue print is, and most of them have probably made or used such prints. It is probable, however, that few people know how the sensitized paper is prepared.

Engineers abroad seem to prefer for duplication of drawings what is known as "block printing," and any one who has seen a print made in a French or German manufacturing establishment must admit the superiority of this process. While the workman in an American machine shop has for his guide a blue print, consisting of white lines upon a dark blue ground, the machinist abroad has before him a print with black lines upon white paper, and in most instances each section and metal is colored with a different tint, which is not feasible upon blue prints.

Blue printing, which was invented years ago by Sir John Herschel, son of one of the most distinguished astronomers and natural philosophers of modern times, still holds the foremost place among processes of obtaining exact duplicates, however, because it is undoubtedly the cheapest and simplest process, and requires the least knowledge of chemistry to understand.

Pure and fresh chemicals, and a paper that has a hard, smooth surface and is pure white in color, are essential to the production of beautiful prints. It is, of course, understood that the drawing to be copied is made upon as clear and as transparent a tracing paper or linen as can be obtained, and that the Indian ink, which is generally used in draughting offices, is as thick and opaque as can be used. Having secured chemicals, etc., it becomes necessary to prepare a sensitizing solution with which to coat the paper, and which is made up as follows: One and three-quarter ounces of citrate of iron and ammonia, dissolved in eight ounces of water, and one and one-half ounces of red prussiate of potash, C. P. (chemically pure), dissolved in six ounces of water. Any water will do, but rain or distilled water is best. These solutions should be kept in separate bottles and in a dark place until wanted for use, when they may be mixed.

An excellent way in which to prepare your paper is to lay it flat on a clean, smooth surface, and apply the solution with a sponge, which, having been dipped into the mixture and about one-half of the contents squeezed out, is passed over the paper from side to side until the sheet is covered. The sponge is then again dipped into the solution, half the contents squeezed out, and passed over the sheet at right angles to the line of the former application. The sponge should then be squeezed dry, and passed over the paper parallel to the line of the first application, to remove all chemical surplus. Too much care cannot be taken in this sensitizing process, as the use of too much solution produces streaks in the print. The paper, when properly coated, will present an even golden color. It must not be forgotten that this must be done in a dark room—that is, a room into which the actinic rays of the sun do not penetrate. Gas or lamp light does not affect the sensitizing solution, and hence the paper may be coated in the evening, or in the day in a dark room furnished with either of these lights. Electric light will not do. The paper, having been coated, is then laid away to dry in a dark, cool, and dry place, and must be absolutely shielded from the sun's light until used.

It will be noticed, however, that prints made from the paper soon after prepared are superior to those made when it has laid for some time.

For making prints, a wooden frame, containing a sheet of French plate glass and furnished with a soft, thick felt and a removable wooden back, to which brass or steel springs are fixed to fasten it in place—a printing frame something similar to that of the photographer's—is necessary. A large frame is different in one particular from the one described. Instead of having the springs attached to the outside of the wooden back, it has one, two or three strips of wood to which the springs are fixed, attached by hinges to the longest side of the frame. The wooden back and felt pad are removed, and the tracing to be copied is laid face downward on the glass. The prepared paper is then placed with the sensitized face upon the tracing, and upon the top of these the sheet of felt. The wooden back is then fixed in place, and the pressure exerted by the springs acts on the soft and elastic felt, and presses the tracing closely and smoothly against the glass.

The frame thus arranged is exposed to the rays of the sun, the time of exposure varying, of course, with the intensity of the light.

No definite directions as to the time of exposure can be given. A little experience, however, will soon teach the blue printer when the print is done. The paper, when sufficiently exposed to the sun's light, will assume a gray tone, when it is to be removed and washed. The condition of the atmosphere determines the time, and an exposure from four to ten minutes in a bright sunlight is usually sufficient, but a well-known engineer, in a recent letter, stated that many prints he had made in London required an exposure of several days. The washing can best be conducted in a tank of running fresh water. When the paper is immersed into the water, the printed side will immediately assume the color of Prussian blue, except where the opaque lines of the tracing obstructed the actinic rays of the sun from penetrating through them, and these will appear in white. When the white lines and the blue background are seen to be fully developed, the copy is hung up to dry.

Chas. E. Emery

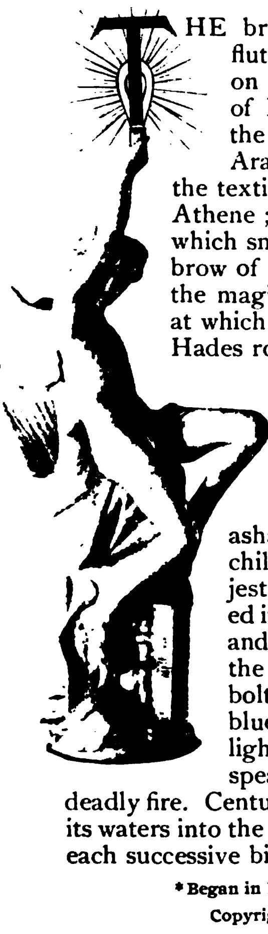
CASSIER'S MAGAZINE.

VOL. IV. JUNE, 1893. NO. 20.

THE LIFE AND INVENTIONS OF EDISON.*

By A. and W. K. L. Dickson.

Eighth Paper.

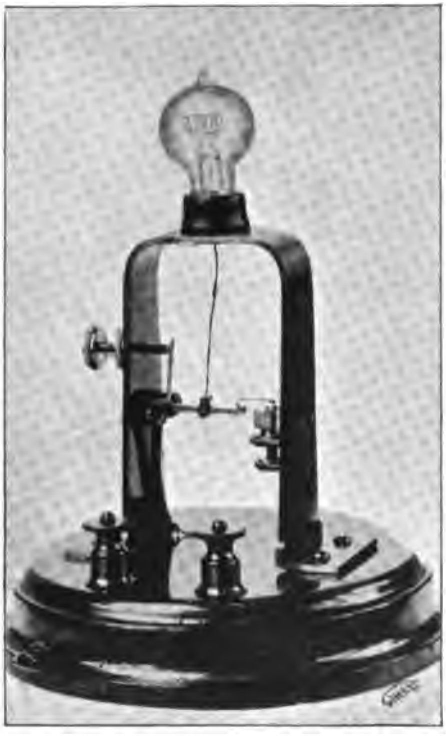


THE breathings of Marsyas' flute which trenched upon the golden harmonies of Phoebus Apollo, and the glowing fabric of Arachne which outvied the textile intricacies of Pallas Athene; the spell of Arion which smoothed the wrinkled brow of ancient Oceanus, and the magic strains of Orpheus, at which the basaltic gates of Hades rolled sullenly back on their adamantine hinges, all these endangered the attributes of Olympus, and the gods themselves became ashamed of their earthly children. But the majesty of heaven entrenched itself in the mysterious and deadly arsenal of the skies, in the thunderbolts of Zeus, the steel blue Aegis of the sheet lightning, the forked spears and chains of deadly fire. Century after century rolled its waters into the gulf of time, and with each successive billow the foundation of Olympus trembled. Most potent and terrible of all was the tidal wave of the nineteenth century, surcharged with human thought and energy, and enfranchised from the spell of superstitious veneration. One by one the deified forces of nature were dragged from their cloudy thrones, and forced to resign their sceptres into mortal hands. Last of all to yield was sovereign Jove, guardian of the celestial fires. Sullenly the sturdy old Titan walked the paths of men; fettered in his own chain lightnings, he swelled their triumphs and speeded their multiform industries; but the shame of his fallen estate burned within him, and over the brightness of his presence he folded the forlorn fragments of his imperial palla, lest his foes, seeing his uncovered face, might mock the more cruelly. Alas! within the last few decades, even this poor refuge has been denied him, and that glorious effulgence, which was the emanation and express image of his person, has been stripped from the dying god, and diverted into independent channels. No longer an object of superstitious horror, maligin and arbitrary in its influence, the incandescent electric light sheds its pure and potent radiance over the uttermost parts of the earth and in its steadfast, searching, yet beneficent

* Began in November issue.

properties supplies no mean correspondent of that better "Dayspring from on high which hath visited us, to give light to them that sit in darkness and in the shadow of death, and to guide our feet into the way of Peace."

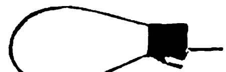
It must be borne in mind that the science of electrical lighting takes its rise from two great fountain heads, the arc and the incandescent. The voltaic arc is the progress of electric sparks between two separated carbon points, and the dazzling nature of its luminous effects is produced by the transfer of intensely heated and minutely subdivided carbon from the positive to the negative electrode. Vital objections to the voltaic lie in the insufficiency of resisting power on the part of the carbon, in its too rapid consumption, and in the need of complicated machinery for the purpose of maintaining a regular current through the carbon electrodes. In the incandescent light, the passage is effected through a substance of high resistance and defective conductivity, such as solid carbon in a state of white heat.



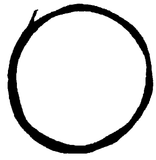
EDISON'S FIRST LAMP.

The first practical contribution to the science of electric lighting was made in 1812 by Sir Humphrey Davy, who produced an arc of marvelous brilliancy, four inches in length, capable of extension to seven inches when placed in an exhausted receiver, and utilizing a battery of 2000 cells. The expenses attendant upon the production of this light were so enormous, and the difficulties with which it was interwoven appeared so insuperable, that the principles of the voltaic arc were abandoned until the year 1834, when Professor Dumas, of Paris, revivified them at the cost of $6 per minute. The enterprise was short-lived, as neither the experimenter nor the French public were in possession of the purse of Fortunatus. Two years later, Daniell introduced a two fluid battery which tended materially toward the supplying of a steady electric current, and, in 1889, Grove's efforts in the line of electric generators gave renewed life to an art which seemed in danger of entire or partial extinction. In 1844 Foucault's utilization of carbon from the retorts of gas works was attended by a marked degree of success, resulting from the superior hardness of the material and its greater resistance to heat. The science was now sufficiently matured to be put into practical operation, and the season of 1844-1845 witnessed the illumination of the Place de la Concorde, Paris, by arc light, under the auspices of an enterprising electrician, named Délénil.

This public test was followed by many others, more or less satisfactory in their results, but the most dazzling and fairy-like display was achieved upon the occasion of the present Czar's coronation, when the utmost resources of the arc light were pressed into service. The capabilities of arc lighting found highest expression in the Jablochkoff candles, the superior attributes of which secured their wide

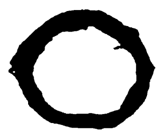


BRAZILIAN FIBRE.

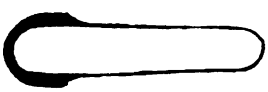


MONKEY BAST FIBRE.

MANILLA HEMP.

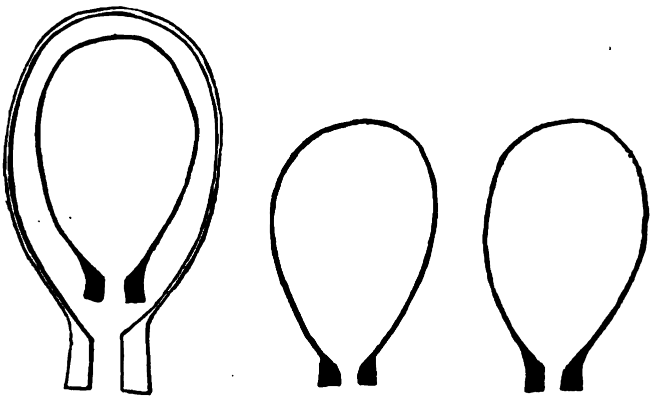


SOUTH AMERICAN BAST.

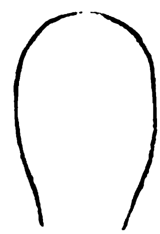


WHITE WOOD CUT BY MACHINE.

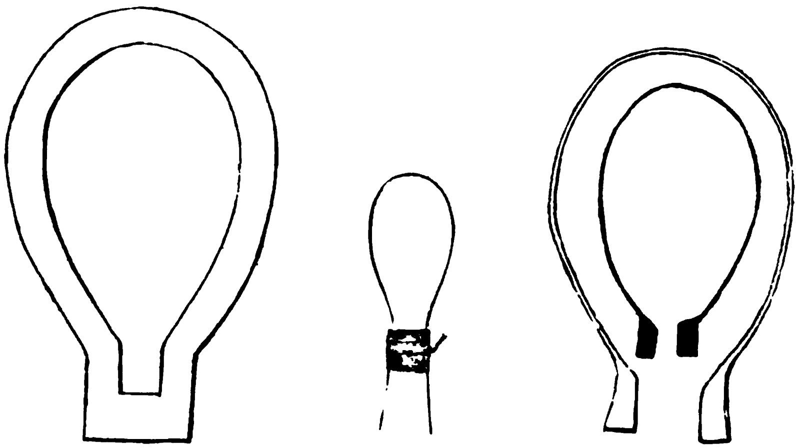
PALM LEAF.



THE OLD PAPER HORSE-SHOE, BEFORE AND AFTER CARBONIZATION.



SOUTH AMERICAN FIBRE.



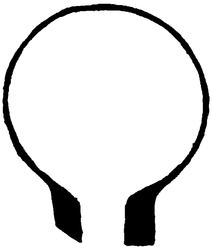
JUTE FILAMENT, BEFORE AND AFTER CARBONIZATION.

REPRODUCTIONS FROM PHOTOGRAPHS OF MATERIALS USED BY EDISON IN HIS EARLY INCANDESCENT LAMP FILAMENT EXPERIMENTS.

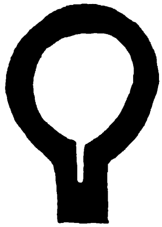
HUNTING FOR FIBRE.—THE EXPLORER'S ASSISTANTS.

introduction into France and England. The peculiar name of the system is derived from the fact that the mechanism is comprised of two cylindrical pencils of compressed carbon, placed side by side, but separated from each other by kaolin, or plaster of Paris. The insulating substance fuses with incandescence, and becomes a conductor at the temperature of the electric arc. The alternating current is used and a flame is thus secured, similar in appearance to that of a wick of a candle.

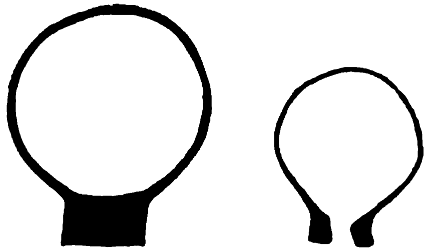
The excellent properties of the Jablochkoff candles were largely neutralized by one glaring defect. While dispensing with the mechanical contrivances, incident to the regulation of the distances between the points of carbon, for the preservation of the light produced, each candle lasted only a few hours, and this entailed a succession of new burners. It was this feature of the system which especially arrested Mr. Edison's attention, and which caused him to merge his energies into the production of an incandescent solid. Some competitive talent in the principles of incandescent lighting was already in possession of the field, but neither in quantity nor in quality could it compare with the results achieved by the rival branch. An American named Starr, in the year 1845, patented in England the first practical application of platinum. In 1847 Dr. Draper, of New York, conducted a series of experiments, based on the qualities of this metel, highly heated. Despretz followed in 1849, with investigations on the subject of sticks of incandescent carbon, immured in a glass globe, the air of which was exhausted or replaced by nitrogen. So completely was this transaction lost sight of, and so thoroughly were the modest pretensions ot the incandescent solid eclipsed by its formidable rival, that in 1873 the St.



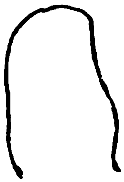
PLUMBAGO FILAMENT.



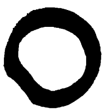
TISSUE PAPER FILAMENT.



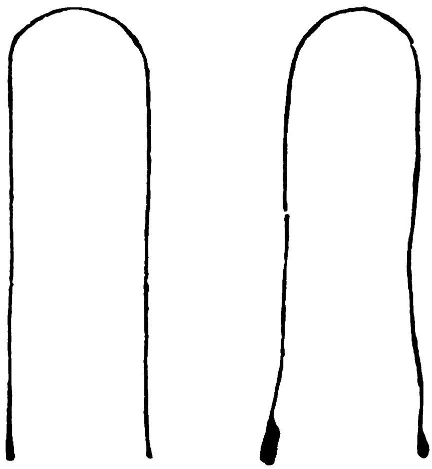
CARDBOARD LOOP, BEFORE AND AFTER CARBONIZATION.



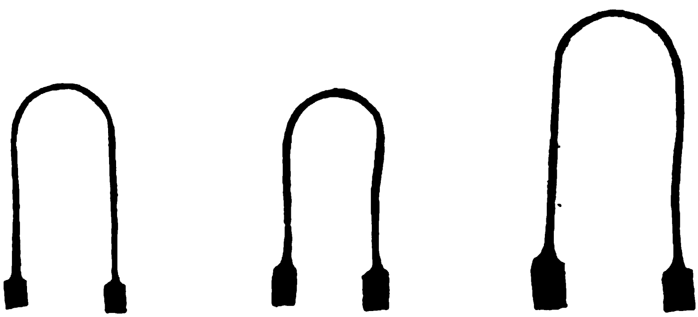
CARBONIZED BAMBOO THREAD.



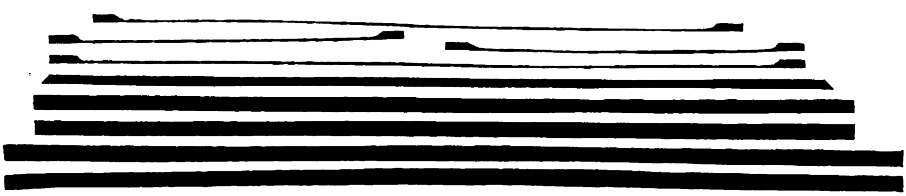
SECTION OF BAMBOO.



BAMBOO CARBONS.

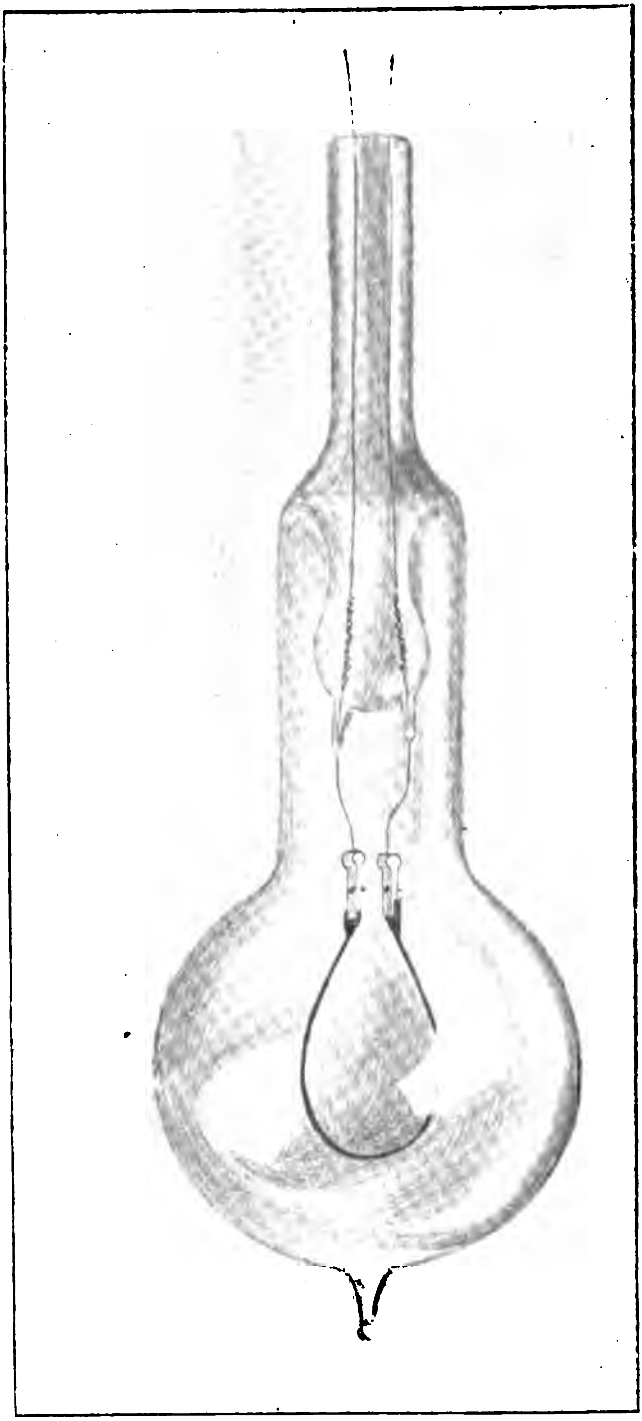


BAMBOO CARBONS TREATED IN HYDRO-CARBON VAPOR.



THE VARIOUS STAGES IN THE PREPARATION OF BAMBOO FILAMENTS AS NOW USED.

REPRODUCTIONS FROM PHOTOGRAPHS OF MATERIALS USED BY EDISON IN HIS EARLY INCANDESCENT LAMP FILAMENT EXPERIMENTS.



ONE OF EDISON'S EARLY LAMPS.

Petersburg Academy bestowed a medal upon a certain electrician named Lodyguine, and later still, letters patent were issued to Messrs. Sawyer & Mann for the supposed original discovery of a stick of carbon, made incandescent in nitrogen, the identical experiment made by Despretz in 1849. It was in the early spring of 1877 that the defects of electric lighting first enlisted our reformer's abilities, and held them enchained until January, 1878, when the fascinations of the incipient phonograph were again asserted. In those brief ten months, however, much had been accomplished, and the incandescent light had assumed a practical aspect which commended itself to the attention of business men. The outcome of this movement was the incorporation in October, 1878, of the Edison Electric Light Company, with a capital of $300,000 and the following directors and organizers: President, Dr. Norvin Greene; secretary, Calvin Goddard; Thomas A. Edison, G. P. Lowrey, Tracy R. Edson, James H. Bowker, R. L. Cutting, Jr., G. R. Kent, N. J. Miller, Robert N. Gallaway, G. W. Soren, G. F. Stone, G. S. Hamlin and E. P. Falbri.

HUNTING FOR FIBRE.—READY FOR A JOURNEY.

On October 16, 1879, Mr. Edison decided that he had reached conditions where he thought a carbon filament might be made into a lamp to insure stability. A cotton thread was the first substance utilized, and a groove in the shape of a hair-pin was cut in a nickel plate, the groove being just wide enough to hold the thread. This was placed in a small nickel mould and filled with charcoal. Five hours were spent in carbonizing and cooking the mould, after which, upon taking it out of the groove, it was found to be of such extreme fragility that it promptly fell

HUNTING FOR FIBRE —CLIMBING FOR A SPECIMEN.

to pieces, even in such practiced hands as Mr. Charles Bachelor's. Repeated experiments were attended by the same disastrous results until a late hour in the night of the 18th, when a filament was rescued intact from its miniature crematory, only to be again fractured in the act of securing it to the conducting wire. "Nature's sweet restorer" had not been invoked by these desperadoes since the commencement of the experiment, on October 16, yet so potent was the spell of inspirational genius, that Mr. Bachelor at once yielded to Mr. Edison's frantic suggestion that they should make a lamp before they slept, or die in the attempt. On the 19th, several filaments were obtained, all of which broke in clamping, but finally, on the morning of the 20th, after many alterations in the clamping devices, a perfect specimen was secured. In carrying this fragile substance the focus of so many hopes, from the laboratory to the glass blower building, a malicious zephyr whirled it from its fastening and reduced it to impalpable powder. Utterly unmanned by this misfortune and unhinged by insomnia and fasting, Mr. Bachelor rushed into the presence of his partner and delivered himself of the following despairing sentiment: "Edison, it's gone, broken by the wind, I'm sick, I'm disgusted. My impression is, that job got too much reputation on a small capital." But,

> "Heav'n has to all allotted, soon or late,
> Some lucky revolution of their fate,"

and upon the morning of the 21st, events assumed a more fortunate guise. A lamp was finally completed, lighted and eagerly watched by the thirty or more experimenters, attracted by the unusual interest of the proceedings. Partially relieved by the success of the trial, Edison, Bachelor, and some others took a few hours sleep, at the end of which time they were greatly elated to find that the lamp was still burning, without any apparent waste of carbon. This delicate thread of light was anxiously watched for several days, after which Mr. Edison decided to raise the candle power very high, in order to see how long the carbon would resist the strain. A greater power was attained than the inventor's most audacious dreams had ventured to picture, and sustained through an anxious period of two days, then the soft glow faded, and the tiny filament melted "Like the baseless fabric of a vision." This was the pioneer flame of the Edison incandescent light.

Scarcely had this lamp been burning twenty-four hours, before the entire force of laboratory experimenters, fired with the new enterprise, was engaged in carbonizing every material which promised to yield the desired residuum of charcoal. Filaments of iridium, platinum and other metals were tested, followed by threads, rubbed with coal tar, plumbago and other substances. Later still, Edison experimented with a horse shoe filament, in which a marked degree of success was obtained, insufficient, however, for the ultimate goal of the inventor's ambition, which looked to the possession of a filament of such inordinate resisting power, as to secure a perfect subdivision of the electric light. In the course of his lucubrations on this subject, a passage of Humboldt suddenly occurred to him, relative to the properties of a certain

HUNTING FOR FIBRE.—A PALM TREE AVENUE IN THE FOREST.

A PATRIARCH OF THE FOREST.

species of bamboo, growing on the banks of the Amazon. A closer examination of the great naturalist's description, convinced him that in vegetable fibres alone could be found the ideal material of which he had been so long in search, and a band of zealous and experienced agents was soon engaged in the work of investigation.

Prominent among these, was a certain Mr. Frank McGowan, a gentleman of Celtic extraction, endowed with the grit and enterprise peculiar to that favored race. The history of his exploits derives added interest from the fact of his sudden and inexplicable disappearance, shortly after his satisfactory discharge of Mr. Edison's commission. Despite the most careful search, in which every imaginable clue was followed up, Mr. McGowan's fate is still wrapped in impenetrable mystery. Two theories divide the field of conjecture. One holds that the daring traveler must have succumbed to the ill health, resultant upon his many hardships, a supposition confirmed by his severe illness immediately upon his return ; the other,—and this view cannot fail to enlist lovers of the romantic, —that Mr. McGowan, in the course of his South American travels, became enamored of a certain lustrous-eyed Senorita, for the better enjoyment of whose society he has withdrawn to the idyllic seclusion of some sweet Eden, within

"Breadths of tropic shade and palms in cluster, knots of Paradise."

The following hitherto unpublished account of an expedition to the Amazon, in conjunction with Mr. McGowan, is furnished us through the kindness of Mr. Samuel G. Burn, a member of Mr. Edison's mining force, and himself a traveler of wide experience. It exemplifies in a very striking manner, the whole-souled way in which Mr. Edison's associates lend themselves to the furtherance of his views :

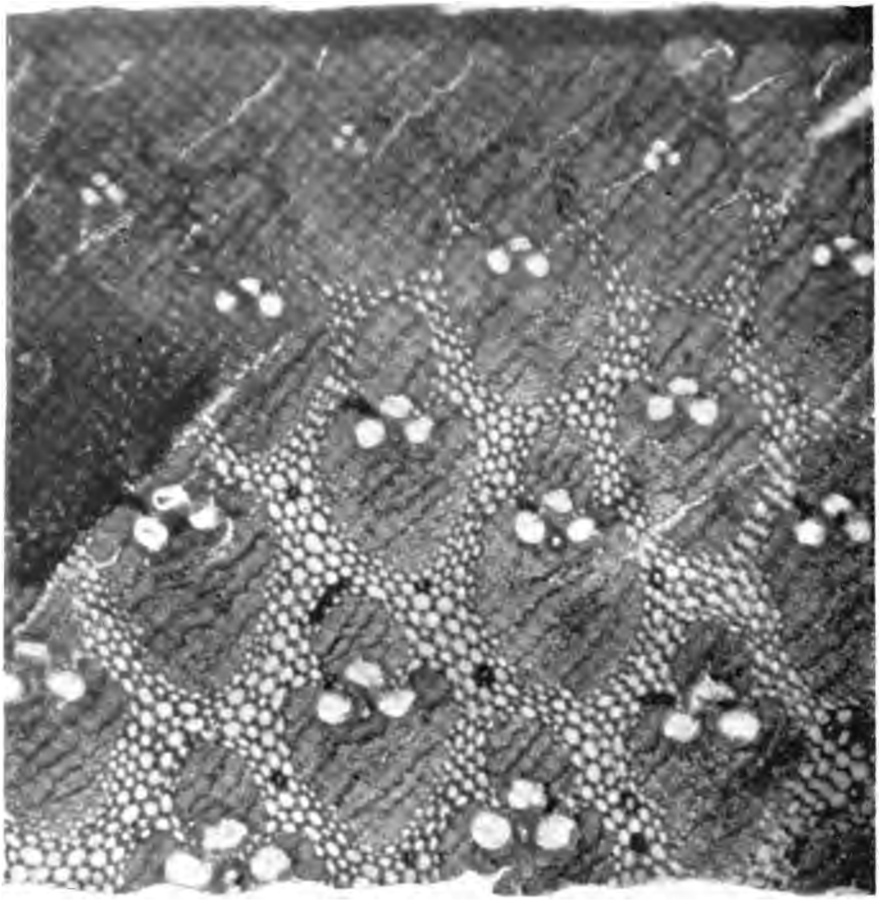
"My recollections of Frank McGowan's explorations from the time he entered the Amazon until we returned together from the Cauca.

"Nothing of interest transpired during the voyage up the Amazon, but when the navigable portion was passed, McGowan's troubles began, through the refusal of his associate to face the dangers of the upper Amazon and the Napo river. These were represented by the native Indians in colors calculated to damp the ardor of a man less inherently brave and conscientious than McGowan, but they only served to whet his determination. 'I'll make the trip, do my duty, or die,' was his sole response to these birds of evil omen.

"McGowan was now thrown on his own resources, supplemented only by the precaution and inefficient aid which he was able to secure from point to point. A few small villages lay on his

ANXIOUS TO BE PHOTOGRAPHED.

route along the Napo river, and from these he hoped to derive information and supplies. The distance between his starting point and Quito was about 500 miles, a stretch the extent of which few of our modern travelers can realize. He commenced by hiring a canoe and several Indians, but, unfortunately, twenty-four hours had not



MICROPHOTOGRAPH OF BAMBOO SECTION.

elapsed before his cowardly guides showed an unwillingness to abide by the contract, stating their fear of the hostile tribes which they were likely to encounter, and predicting darkly, that if persisted in, this expedition would result in the death of all the parties involved. It was only by the exercise of his national 'gift of the gab' that McGowan finally allayed their fears and succeeded in inducing them to proceed. The society of these gentlemen was attended by some inconvenience, for although harmless in other respects, they were inveterate thieves, and a strict watch had to be maintained day and night upon the jewelry and other valuables deposited at the bottom of the boat. One Indian alone furnished an exception to the predatory instincts of his mates and was retained throughout McGowan's journey to guard his interests, while the other explorers were engaged in the search for bamboo.

"It was after one of these exploring trips that the Indians finally struck, demanded a settlement of their claims and departed in a body, taking pains to assure McGowan and his one faithful adherent that they would never live to reach Quito, that journey being attended, in the Indian mind, with the most insurmountable dangers. The two were now alone, having been deserted at the end of thirty-six hours. New

Indians were hunted up, and by dint of bribes and other substantial stimulants, were imbued with sufficient courage to undertake the exploration of new sections of the Napo river. It was seldom that these primitive regions afforded any shelter, and when found, it was impossible to remain in them, on account of the flies and other insects. Peaceful sleep could only be enjoyed on sand-bars, or in the canoe, tied to a stump, whenever rain seemed imminent. A strict watch had to be kept on the rise of the river, lest the sand-bars on which they were sleeping should be deluged, and the sleeper, blankets, provisions, etc., be carried down the stream. Food could be secured only at intervals, and only by the exhibition of the big shining *peso*, a coin with which McGowan had been bountifully provided. At such times, provisions for several days were bought, and added to the other stores of the loaded canoe. After eighty-five day of toil and privation, Quito was reached, a triumphant vindication of pluck and energy.

HUTING FOR FIBRE.—SOME LEADING NATIVES.

"The most startling feature of the trip occurred one day while McGowan and his force of Indians were investigating a tract of land, situated about five miles from the Napo river. The different members of the party were scattered, each searching for the desired bamboo, but the leader took care that they should be within hailing distance, so as to be promptly recalled in case of danger. His precautions proved salutary, for an unusual sound was suddenly heard, which brought every man to the meeting point agreed on, just in time to engage in a general fight with a tiger.

"After spending some time in Quito, McGowan journeyed to Quayaquil, from there, by steamer, to Buenaventure, and thence by rail, twelve miles to

Cordova, this being the full length of the complete road. From Cordova, McGowan started out on foot, sending his baggage by mules, to examine the territory between this point and Cali, or the Cauca valley, a distance of seventy-five miles. Some patches of the bamboo were located on this trip, none of them exceeding four inches in diameter, or forty feet in height. After reaching Cauca a more prolific region was entered, for almost anywhere between Cali and Popayan, or head of the Cauca valley, more especially along the banks of the Cauca river, the bamboo grows seventy-five and a hundred feet high, and from six to nine inches in diameter. The graceful curves of the tops of this beautiful grass, towering high above the trees, presented a most striking contrast to the surrounding foliage. It was found that the grass was not confined to the Cauca valley, for following up the mountain rivers, all of which empty into the Cauca, patches of the bamboo were discovered to be numerous, not only in flat places, but in the mountains, being thoroughly moistened by springs. The grass develops to an enormous size, and here it seems the strongest and most healthy. The joints of many of this kind exceed those in the valley, reaching twelve to thirteen inches in length, and eight to nine inches in diameter. Some of these patches are acres in extent, and nothing grows there but the grass and ferns, which are indescribably beautiful and vigorous."

HUNTING FOR FIBRE.—A GROUP OF NATIVE CHILDREN.

The bamboo secured was of a superior quality, but was finally abandoned by Edison in favor of a Japanese variety, the fine fibre of which was found to meet the varied requirements of the incandescent lamp, furnishing a conductor of the requisite resisting power. In the selection, seasoning, and carbonizing of the material, the greatest care and discrimination were necessary. No fewer than eighty varieties of bamboo and 3000 kinds of vegetable fibre were tested successively, and it was found that of this incredible number, only some three or four possessed the desired attributes. The sole portions available were the delicate fibres, immediately underlying the bark, and these, under certain conditions of maturity and seasoning, were subjected to a special process of carbonizing, resulting in the elimination of all volatile matter, and the presence of a cellular structure, admirably adapted for the purposes required.

(*To be continued.*)

THE BLOWER SYSTEM OF HEATING AND VENTILATING.*

By Walter B. Snow.

IN the atmosphere of the open country there is present from three to four parts of the carbonic acid gas in 10,000 parts of air, while in that of an enclosed apartment in which a musty odor is barely perceptible to one entering from out of doors, there will be found not less than six or seven parts in the above named volume. Good ventilation is measured by the presence of not more than six parts, and fair ventilation by not more than eight parts of carbonic acid gas in 10,000. It is readily deducible that to maintain a proportion of six or eight parts in an apartment continuously occupied by a given number of persons, will require 3000 or 1500 cubic feet of air per hour per individual, according to the proportion of carbonic acid.

An ordinary school-room containing fifty-six pupils and teacher would thus hourly require from 171,000 to 85,500 cubic feet, equivalent to passing through the room once in every five to ten minutes a volume of air equal to its entire cubic contents. The State Inspectors of Massachusetts require thirty cubic feet of air per pupil per minute, for school-house ventilation—not from hygienic deductions, but because it appears upon investigation to be the practical limit attained by existing methods in this Commonwealth. Their original attempt to secure fifty cubic feet of air per head per minute, would have resulted in remodeling, with scarcely an exception, every school building in the State. Financial outweighed hygienic influences, and the limit was dropped to thirty cubic feet.

Almost all existing systems, particularly those installed prior to the last decade, depend for the necessary air movement either upon the natural action of vent flues and foul air shafts or upon their increased efficiency due to heated stacks or steam coils. All such methods are, however, largely at the mercy of climate conditions. As the external temperature rises, they must of necessity become less effective; heavy winds will ofttimes reverse their action and damp and muggy days are noticeable in their effects. They are unstable, untrustworthy. Some means, always positive, always reliable, must be adopted. Nothing short of a positive acting mechanical device is capable of accomplishing the desired results. The fan blower stands pre-eminent as most economical of powers for air volume moved, as most easily applied and most readily operated.

The past ten years has witnessed the rapid introduction of the fan, not only as an adjunct to old systems of ventilation and heating, but more prominently as the primary feature of a newly developed method of hot-air heating. The blower system of heating and ventilation as herein described comprehends only that method by which ventilation is secured under plenum conditions, that is, when the air is forced into, rather than exhausted from, the building, and comprises in its completeness a steam heater or heater, a fan, driven by some type of motor, and a system of ducts and flues through which the air is forced to the various apartments of the building.

Although the State law now requires adequate ventilation in factory buildings, yet it must be admitted that, in the introduction of the blower system the owner's first motive is usually mercenary rather than humanitarian, but the blower system fortunately possesses this particular feature, considered solely

* Abstract of a paper presented to the Society of Arts of the Massachusetts Institute of Technology, Boston.

as a heating system—namely, that in order to heat successfully, it is necessary to supply a volume of air sufficient to, at the same time, thoroughly ventilate any ordinary factory structure where the processes are no more ordinarily objectionable. The introduction of the blower system is therefore divided between two great classes of buildings. First, where heating is pre-eminent and ventilation is merely incidental; and, second, where the system of ventilation is of primary importance, and heating is necessarily combined with it for successful operation, rather, than introduced as an independent system.

To the first class belong, almost exclusively, all manufacturing buildings, storehouses, drying-rooms, exposition buildings, and some offices and stores. In the second class are these buildings in which specially objectionable processes are carried on, hospitals and asylums, all halls of audience, including theatres, churches and schools, and stores and offices not included in the first class.

The enterprising manufacturer is quick to appreciate his financial interest in the provision and maintenance of an atmosphere in his factory that exhilarates rather then wearies his employees; for a direct monetary return can be shown in the improvement in quantity and quality of work resulting from the introduction of the blower system with pure air and a comfortable temperature. The blower system has met with special approval at the hands of the manufacturer on account of the utilization of his exhaust steam without imposing unnecessary back pressure on his engine. Doubtless one great element in its success in the mill and factory has been the usually excellent attendance which it receives. Every manufactory of reasonable proportions has its own power plant, and its own engineer to whom is usually assigned the control of the heating system. Considerations of economy, and the before-mentioned idea of the owner that heating is the pre-eminent feature desired in the application of the system in a factory, have much to do with the location of the apparatus. To secure economy in heating, where improved ventilation does not enter into the question, the apparatus is frequently arranged so as to take its air supply entirely from within doors, thereby simply turning the air over and over within the building. As the cost of ventilation is necessarily measured by the volume of air at the temperature of the room, which is removed, or caused to escape in a given time, it is obvious that this expense may be practically avoided by the above-mentioned plan of turning the air over and over. There is even then an incidental leakage resulting in a degree of ventilation considerably in excess of that occurring with any system of direct steam heating. To this end, in a one-story structure, the apparatus should be placed as near the centre as possible so that the air may be drawn back to it from all sides.

Dependent upon the character and construction of the building, one of two general methods of distribution may be adopted. The first and most common is by a more or less extended system of metal ducts or pipes, almost universally constructed of galvanized iron on account of its durability. Such a system is the only one practicable in wooden structures. In brick buildings, particularly those of two or more stories, brick ducts and brick vertical flues are the most convenient, and, as usually applied, do not encroach upon valuable interior floor space.

The one-story structure with brick, wood or metal sides, with sloping roof surmounted by skylight or monitor, forms to-day the model for the foundry and the machine, boiler or blacksmith shop, while its use is rapidly extending to other trades. In such a building some arrangement of galvanized iron distributing pipes is compulsory, for the brick duct and flue becomes too expensive proportionate to the cubic contents to be heated.

The ideal installation of the blower system is in the three or four-story brick factory of the type of the ordinary cotton mill, where the heated air is

conducted from the apparatus through the basement to the bases of special pilaster flues located at regular intervals along one side of the building. The duct itself is constructed of brick extending along the interior of the basement wall, and is provided with either a flat top of approved and air-tight material, or is made quadrant in form, securing for a given expenditure of material the maximum area for passage of air.

At distances varying from forty to seventy-five feet, the piers between the windows are carried out and form the pilaster flues which in this climate should be constructed with eight-inch outside walls, two-inch air space, and four-inch outside walls, in order to prevent excessive loss of heat. These flues are seldom lined but should be laid and pointed as smoothly as possible. Upon each floor, at least one foot below the main floor timbers, which are supported by the piers, there is placed in each flue a special damper. The damper itself as it is opened extends into the flue and acts as a deflector to throw a portion of the air into the room, this proportion being controlled by the operating mechanism.

Most prominent among the buildings in which ventilation may be considered of primary importance are those in which persons remain for several hours closely seated, and practically inactive, as is the case with an audience in a church or theatre and with the pupils in a school-room. Here the per capita air space in the room is at its minimum. In the best modern school-room there is usually an allowance of 250 cubic feet of space per occupant, but in many theatres and halls this figure is reduced as low as seventy-five to 100 cubic feet to each person. In the ordinary school-room a supply of thirty cubic feet per head per minute would necessitate changing the entire volume of the room once in about eight minutes, while in a hall with only seventy-five cubic feet of space for each member of the audience, such a supply of air would require a complete change once in every two and a half minutes. It is extremely difficult, in fact practically impossible, to so introduce such an excessively large volume of air under these latter conditions without creating objectionable drafts about the occupants.

In this climate, a perfect system of heating and ventilation applied to a building of the aforementioned class should, first, maintain within each room a mean temperature of seventy degrees Fahrenheit, irrespective of changes in external temperature, with a total variation of not over two degrees above or below this mean in any occupied portion of the room. Second, supply to the room under all conditions of indoor and outdoor atmosphere a constant pre-determined volume of air and deliver it without creating objectionable drafts, and in such a manner as to be thoroughly and efficiently distributed throughout the apartment.

This second requirement may be even so exacting as to demand a constant indoor temperature with variable supply of air proportioned to the number of persons occupying the room at any given time. Assuredly, with no arrangement or device can the air supply be more readily proportioned to the requirements than with the blower system. Doubtless, at the present time, more attention is being given to improvement in school-house ventilation than to that of any other class of structures, therefore a discussion of the application of the blower system to buildings of this type must throw a strong sidelight upon the methods to be adopted in all so-called halls of audience.

As has already been shown, the ordinary school-room requires a change of air every eight minutes on a basis of thirty cubic feet per pupil. To effect this equable distribution within a room twelve to fourteen feet high, the air must be allowed to enter at some point reasonably distant from the occupants. An opening in the wall above head level fulfills this requirement, and if placed in an inner wall of the building the arrangement permits of the air being discharged in a mass toward the

cold exposed surface, of course spreading out fan-shape in its passage across the room until it reaches the outer wall, in a more or less extended volume, according to the quantity and velocity of the air. Here, slightly cooled by the exposed wall, it slowly sinks, owing to its increased density, and tends to spread out upon the floor. If a ventilation opening has been provided at the floor level in the same interior wall from which the air is discharged, a return current of very low velocity, at a lower level than that of the hot air, is created toward the outlet opening, whence the now vitiated air may be discharged out of doors.

The ordinary school-house with its brick partition walls presents a most excellent opportunity for the economical placing of the necessary flues, for they may be grouped along the interior walls and provided with inlet openings about eight feet above the floor and vent openings at floor level. A flue serving to supply hot air to the first floor may, by the insertion of a header above the heat opening, serve also as vent flue for the room above. By making the area of the vent register and flue the same, respectively, as that of the supply register and flue, the discharge of air at a lower velocity than it enters is sufficiently restricted to produce a plenum condition within the room, not only preventing inward drafts but compelling the surplus of air to escape through cracks, crevices, and even through the porous walls.

The varying exposures of the rooms of a school building require that more heat shall be supplied to some than to others. The sunlit southerly room, perhaps still more favored by being over the boiler, may be kept perfectly comfortable with a supply of heat that perchance will barely maintain a temperature of fity per cent. to sixty per cent. Fahrenheit in a room on the opposite side of the building, exposed to high winds and shut off from the warmth of the sunshine. With a constant and equal volume of air supply to each room, it is evident that its temperature must be directly proportional to the cooling influences within and around the room and that no building is properly heated and ventilated where the temperature cannot be varied without affecting the air supply. To this end, air of a given temperature may be conducted to the base of each flue and there tempered to a degree suitable to the requirements of the room supplied. Two methods appear.

The older arrangement consists in heating the air by means of a primary coil to about sixty degrees, or to the minimum temperature required within the building. From the coils it passes to the bases of the various flues and is there still further heated by secondary or supplementary heaters. Under the second and more recent method, a single heater is employed, the supplementaries are discarded and all the air is heated to the maximum required to maintain the desired temperature in the most exposed rooms, while variety in temperature of air supplied to the other rooms is secured by mixing with the hot air a sufficient volume of cold air at the bases of the respective flues.

This result may be best accomplished by designing a hot-blast apparatus so that the air shall be forced rather than drawn through the heater and by providing a by-pass through which it may be discharged without being heated. Extending from the apparatus is a double system of ducts. At the base of each flue is placed a mixing damper usually controlled by chain from the room above and so designed as to admit either a full volume of hot air, a full volume of cold air, or to mix them in any desired proportion without affecting the resulting total volume delivered to the room. Where perfect regulation, independent of the teacher, is desired, the damper may be operated by a thermostat in the room, with which the flue connects. The hot and cold system, as this is familiarly known, accomplishes at less expense, with greater rapidity and equal certainty, the results obtained by the more complicated method previously described and is being extensively introduced in the modern school-house wherever the

blower system is applied. The hall and the church are in reality but enlarged school-rooms as regard their treatment by the blower system. The same vital requirements hold, that the temperature must be maintained independent of volume of air admitted, while the difficulty of satisfactorily admitting the required air supply is increased by the closer seating of the audience.

The theatre presents far more complication than the hall ; its three parts, stage, auditorium and lobbies, may at one moment be essentially one, and the next be rendered practically independent. The auditorium is usually thoroughly protected by the lobbies or the walls of adjacent buildings, so that the heat loss is reduced to a minimum, and during a performance it becomes a question of cooling rather than warming the occupants. Admission of air through the floor and removal through the ceiling is necessary to perfect success when gas is used, but in these days of electric light the direction of movement may be reversed with marked success.

One of the most notable examples of this method is in operation in the New York Music Hall. The main concert hall, seating 3000, and the recital hall, with a capacity of 1200, are supplied entirely through perforated ceilings, whence the air passes down over the persons of the audience and escapes through a multitude of openings in floor and risers. This unnatural movement of the air against its own impulse must be facilitated by exhaust fans connected to the area beneath the floor in addition to the plenum fans for forcing in the fresh air. The rapid improvement in theatre ventilation certainly indicates that the enterprising manager sees therein another inducement to the theatre-going public to patronize his individual house in preference to the one where the air is foul and oppressive, although the dramatic attraction may be equally good.

The requirement of large air volume per capita in hospitals and asylums, particularly in contagious wards, necessitates positive and ample means which can only be met satisfactorily by the fan, standing as it does, capable, according to its size, of supplying any amount of air required.

The store, with its extended floor areas, and the office building, with its multiplicity of small rooms, call for arrangements peculiarly their own. Construction practically forbids and necessity does not as a rule demand vent flues in such structures, for under the ordinary conditions of occupancy of an office the air required simply for heating sufficient in volume to average fifty cubic feet per person per minute openings around window frames, porous walls and openings to the corridors, afford ample opportunity for escape of this air. The readiness with which the blower system has been appreciated and adopted is nowhere better exemplified than in the radical departure in steamboat heating. At the present time nearly a dozen of the ferry-boats plying between New York and its adjacent cities, are fitted with a special system of hot-blast heating, arranged somewhat on the hot and cold duct principle, so that the temperature may be regulated without effect upon the air volume delivered. Plans are now being prepared for the introduction of the system in a number of the new transatlantic liners.

The ready adaptability of the blower system to diverse conditions forms some of its salient features. Not only is it a success as a heating and ventilating system, but as a means of drying materials of all kinds, of humidifying the atmosphere when desired, and of cooling in summer by drawing the air across iced or cooled surfaces. The public at large has been slow to appreciate the necessity of ample and thorough ventilation, but in this State at least, the building and State inspection laws keep the subject ever before the eyes of the proprietor, the architect and his client. The familiar criticism against better ventilation is its cost, both in application and running expenses. It appears expensive because of our habit of measuring comfort by the temperature rather than by the purity of the atmosphere.

When we become accustomed to being well ventilated we shall form the habit of paying for it without appreciating the expense.

As the mission of ventilation is to remove foul and supply fresh air, it is at once evident that in this process of removal there must be continuously carried from the room a large amount of heat, for all the air escaping must be of the same temperature as that of the room itself. This loss is incidental to any system or arrangement, by which ventilation is secured, and it must be made good by imparting the necessary surplus of heat to the air admitted. It is not strange, then, that the cost is greater in heating a well-ventilated room than one which is tightly closed.

The advantages of the blower system may be summarized under two main heads: First, adaptability and convenience; second, efficiency and economy. The early consideration of the system, before the plans of the building are completed, has of course much to do with its adaptability and the convenience with which it may be introduced. The centralizing of the entire heating surface in a single room avoids all danger by fire, prevents the possibility of damage by leakage and removes all anxiety regarding the freezing incident to isolated coils. A single valve serves to control the temperature of all air admitted to the building, so that the thoroughly installed system, with its governor engine, automatic return-water apparatus, damper regulator and its thermostatic control, is rendered so completely self-controlling that the attendant's care is usually reduced to supplying sufficient coal to the boiler. The system is positive in its action at all times, the air is put where it is wanted, not merely allowed to go. The pressure created within the building is sufficient to cause all leakage to be outward, preventing cold inward drafts and avoiding all possibility of drawing air from any polluting source within the building itself. Absolute control may be had over the quality and quantity of air supplied. It may be filtered and cleansed, heated or cooled, dried or moistened at will. By means of the hot and cold mixing damper the temperature of air admitted to any given apartment may be instantly and radically changed.

The efficiency and economy of the system must, of necessity, be considered under first cost and running expense. Circumstances so decidedly alter cases that an arrangement economical and easy of introduction in one building may prove very expensive in another. In the majority of cases, however, the blower system, regarded simply as a method of heating, may be installed for less money than any other system of equal efficiency. Wherever the flues can be formed in the walls, and the distributing ducts are of moderate extent, the system will figure less in first cost than any other capable of attaining the same results and of supplying the same amount of air. The primary cost of a fan is less than that of any other device for moving the same amount of air. The large volume of air passing through the heater causes a condensation of steam so great that one foot of heating surface is rendered the equivalent in efficiency of three to five feet in the form of the ordinary direct radiator exposed in the room, This saving in heating surface offsets the additional cost of fan and motor.

As directly bearing upon this point Professor Woodbridge has stated, with regard to the installation in the Walker building, that the saving in piping due to rapid condensation in the coils, as there arranged, was sufficient to pay for the fan, together with an attached engine, had that arrangement been adopted. In all fairness the operating expenses of any system must be compared upon a basis of similar conditions. The blower system, when taking its air from out of doors, cannot be properly compared with any system of direct radiation, for in the latter is lacking the advantage of the ventilation incidental to the operation of the former. But when the blower system rehandles and reheats the air within the building, without outside supply, the comparison becomes more reasonable, although there

will still continue to be a considerable change of air due to leakage.

A six months' continuous test at the Globe Yarn Mills, Fall River, has presented data exceptionally valuable for comparison. Of two mills nearly equal in size and equally exposed, one was fitted with an overhead direct-heating system, the other with the blower system. In mill No. 1 the average temperature was seventy degrees; in No. 2, seventy-eight degrees. The cost of fuel per unit of space warmed was, however, in the proportion of 100 in the direct-heated mill to only sixty-four in the mill heated by the blower system.

The cost of janitorial service enters as an important factor in any building other than a manufactory. The blower system has been adversely criticised because of the experience required in its operation. In point of fact it has been attempted by committees and school boards to place the control of the system in the hands of men who could sweep floors and shovel coal, but did not know the difference between a boiler and an engine. It is not greater intelligence, but a different order of intelligence, that is required. When exhaust steam, that would otherwise be thrown away, is utilized in the heater, its cost must be considered as practically nothing. The condensation in the heater of all the exhaust steam from the special fan engine reduces the cost for motive power to a minimum. As to comparisons regarding cost of repairs, much may be said pro and con, but the character of the machinery, its few parts, slow speed of engine and fan, the sectional construction of the heater, the lack of complication of valves, the concentration of the plant at one point, and the fact that it is under the care of one man are greatly in its favor.

LEADING AMERICAN ENGINEERS.—C. E. EMERY, PH.D.

PROBABLY few American engineers have become more widely known during the past few years than Dr. Charles Edward Emery, of whom an admirable portrait, prepared from a recent photograph, is given in this issue. Dr. Emery is a descendant of an English branch of the Emery family which settled at Newbury, Mass., in 1635, and of which representatives spread over New Hampshire and Vermont, and, to some extent, to all parts of the United States.

He was born on March 29, 1838, at Aurora, N. Y., and was originally educated at the Canandaigua Academy, N. Y., but he has always been a student, and familiarized himself with various special branches of engineering from time to time. His practical engineering experience commenced while still at school. One of the engineers on a branch of the Erie Railroad, terminating at Canandaigua, took D. K. Clark's work on the locomotive in numbers, which were lent to young Emery, who read them in detail, and explained them to the enginemen in the roundhouse at night. The engines had been run on that division without repair for over two years, and the valves were working badly on account of lost motion. Young Emery recommended that the eccentrics be advanced to restore the lead, and the boy of sixteen, with wedges in hand to try the valves, superintended the operation, while the gray-headed men pinched the engine along the track and reset the eccentrics as directed. The youth ran one of the locomotives over the road, under the eye of the engineer, to try the effect, before he had strength enough, unaided, to "hook back" for expansion. The results were quite satisfactory.

As a youth, he built his first engine

with a jack-knife, gimlet, and three-cornered file. It had wooden connections, wooden fly-wheel spokes, and a syringe for a cylinder, but the leaden cylinder ports were capped by an iron plate, which, with type-metal valve, were cut accurately to scale, and operated by a valve gear, designed by him, in which the principal motion was given by a link on a stationary centre, the lead being obtained independently from the cross head, exactly as in the well-known Waelschaert valve gear, long after brought out in Germany, and embodied in the heavy pushing locomotives in Belgium, in the Fairlie type of engines built by the Mason Locomotive Works, at Taunton, Mass., and in some steamships by Bryce Douglas. Another model showed the germ of one of the radial valve gears now in use. The boiler used with this engine was improvised from a stove-pipe, wooden heads being nailed in and made tight by boiling bran inside. The fire was necessarily only in contact with the centre of the length of the pipe, and the engine was operated on Saturdays for the edification of the children and many of the grown people of the neighborhood.

We next find Dr. Emery in the drawing-room of a railroad office, subsequently learning the details of mechanical work in a country shop, where he helped in the foundry, ran the engine, operated iron and wood-working tools, made drawings of machinery or prepared cases for the patent office, as circumstances required. Next, at the solicitation oi friends, he studied law two years with a view of becoming a patent lawyer, and at odd times busied himself as a land surveyor, and in making land maps and drawings of new buildings. The first shot at Sumter found him on a sick bed, but soon after he was zealously organizing a military company, which was disbanded on account of the premature proclamation of President Lincoln that no more troops were needed. A short time later, Dr. Emery entered the regular United States Navy as assistant engineer, and participated, on the United States Steamer Richmond, in the engagement at Fort Pickens, the capture of New Orleans, and the naval attacks at Vicksburg and Port Hudson. His first experience at sea was on a vessel having horizontal screw engines with single poppet valves, operated by enormous rock shafts and lifters, and controlled by dash-pots, one of the first Sickles-Dickerson adaptations. He was promoted and ordered next to the Nipsic, the first of the new class of fast gunboats, stationed off Charleston. The engineers had the reputation of carrying all the steam required to make fast time, and an official trial was finally ordered, with the steam pressure limited to forty pounds. The vessel easily beat the sloop of war Canandaigua on a run from off Charleston to Port Royal entrance and back, the vessel averaging only about eleven knots, though capable of twelve without restrictions, which was very fast for those days. Some suggestions made by Assistant Engineer Emery as to experimental steam apparatus reached the ears of Engineer-in-Chief B. F. Isherwood, who ordered him to experimental duty at the Novelty Iron Works, N. Y., where he had unusual opportunities for several years.

Dr. Emery resigned from the Navy on January 1, 1869, and was engaged for a year in making experiments for the Novelty Iron Works in connection with the proposed manufacture of stationary steam engines, and prepared the elaborate circular afterward published in book form by the vice-president, the late lamented W. P. Trowbridge, entitled, "Condensing and Non-condensing Engines." Dr. Emery was engaged in the fall of 1869 as the general superintendent of the American Institute Fair, it being at the time arranged that he should go back to the Novelty Iron Works as general superintendent. The directors, however, chose to close the establishment, and Dr. Emery entered into business for himself as consulting engineer and patent expert, writing occasionally for scientific papers. He had previously, however, been appointed Consulting

Engineer of the United States Coast Survey and United States Revenue Marine, in connection with which he was also made superintendent of some work for the Supervising Architect of the Treasury Department. Dr. Emery built several new vessels for the United States Coast Survey, and was actively interested in the revival of the compound engine in this country. The first engine built, that for the United States Coast Survey steamer Hassler, was probably the most economical engine of its size ever constructed. Reports on file show that the vessel, with a displacement of 400 tons, made with half boiler power, a speed of eight knots, most of the time running a line of soundings, on a consumption of two and one-half tons of coal per day. While in the naval service at the Novelty Iron Works, Dr. Emery was employed as consulting engineer by the Hecker Brothers, of this city, to initiate and superintend repairs to the engines and the construction of new boilers, by which the output was increased fifty per cent. in the larger mill. To his credit, be it stated, that another engineer finally worked into the place on the plea that Emery was so much in favor of compound engines that he was not to be trusted.

The Coast Survey appointment terminated when the naval engineers were ordered to the vessels; that of Consulting Engineer United States Revenue Marine was continued some twenty-one years, until 1891. In this service the machinery for twenty new vessels was constructed under Dr. Emery's direction, and that of all the others several times repaired and remodeled. In 1874 an opportunity was embraced to place three different types of machinery in three hulls of the same size, one a long stroke, high-pressure, condensing engine; another a short stroke, low-pressure condensing engine; and another a fore-and-aft compound condensing engine. These vessels, as well as a subsequent one, in which the cylinder of a high-pressure condensing engine was jacketed, were thoroughly tested by a joint board of engineers from the Navy and Treasury Departments, Chief Engineer Charles H. Loring representing the former, Dr. Emery the latter. The results were, at the time, the only reliable ones extant, and the printed reports and an analysis of the same by Dr. Emery were copied in text books and technical literature at home and abroad. The degree of Doctor of Philosophy was conferred upon him soon after.

Dr. Emery was one of the judges at the Philadelphia Centennial Exhibition, on engines, pumps and mechanical appliances, and an associate member of the scientific committee on musical instruments, electrical and other scientific apparatus. In 1869, Dr. Emery, while continuing his connection with the Revenue service, became the chief engineer and finally manager of the New York Steam Company. He designed and built the entire plant, providing four stories of boilers, aggregating 16,000 horse-power at the Cortlandt street station, using wrought iron pipes of the largest size it was then possible to obtain (some fifteen inches and even sixteen inches in diameter), designing special expansion joints and other details, and making the work a complete mechanical success. Steam was supplied through service pipes, eight inches and ten inches in diameter, to buildings like the Produce Exchange, the Mutual Life building, and finally, the NewYork court house and Post-office at distances of one-half to three-quarter miles from the station. The work operated very satisfactorily, and the plant is still in operation under the original pressure of eighty to eighty-five pounds. It has been of the greatest value to property interests along the line of the pipes. The older buildings are enabled to compete with the larger, newer ones by putting in modern improvements, such as steam heating, elevators, ample water supply and the like. Basement offices previously overheated by boilers have become desirable property, and lofts in some of the side streets which were formerly rented for a nominal sum are now in demand for manufacturing purposes.

A smaller steam station was erected on Fifty-eighth street near Madison avenue, the building being treated architecturally in keeping with the dwellings surrounding it. The steam supply there too proved a great convenience to residents along the line. Dr. Emery resigned from his position with the New York Steam Company in October, 1887, up to which time there had been expended on the work nearly $2,000,000, and continued business as consulting engineer and engineering expert in relation both to practical matters of engineering and those arising from litigation in patent cases, condemnations of water power, etc. Dr. Emery has been consulting engineer of the terminal facilities of the New York and Brooklyn Bridge and several of the principal plants of the Edison Electric Illuminating Company. He was for a number of years consulting engineer of the city of Fall River, Mass., and prominent in connection with the compromise of the difficulties between that city and mill owners; resulting in a novel agreement, based on his report, by which water was to be thereafter furnished to the city from the Watuppa ponds in consideration of the abatement of taxes on water power. He has been connected with the building of steam yachts, a subway company and a number of similar enterprises. He lectures at Cornell University, and occasionally before other educational institutions, and while in the Government service was chairman of the engineering examining boards of the United States Revenue Marine. He has been for a number of years a member of the American Society of Civil Engineers, the American Society of Mechanical Engineers, the American Institute of Mining Engineers, the American Association for the Advancement of Science, and of the British Institute of Civil Engineers, receiving from the latter a Watt medal and a Telford premium for an approved paper.

Dr. Emery has during the last few years been giving very considerable attention to the subject of electricity and its practical applications. He became a member of the American Institute of Electrical Engineers and read before them several papers, one discussing mathematically at considerable length the vexed subject of the theories of magnetization. Another paper was on the relative economy of steam engines, applicable particularly to electrical work, but of great value in other directions. He is now preparing for the practical introduction of some new electrical apparatus constructed in accordance with principles developed by a long series of experiments with models specially designed for the purpose.

WASTE FURNACE HEAT UNDER STEAM BOILERS.

By Daniel Ashworth, Mem. Am. Soc. M. E.

IN the field of fuel economy as applied to iron and steel manufacturing in the various sections of the country, the most attractive point, promising the greatest results, seems to have been the utilizing of waste heat and escaping gases from puddling and heating furnaces for steam generation. To such an extent has interest been awakened in this direction, that a general revival has taken place in this line. In speaking of it as a revival, I would express the idea that the principle of placing boilers over furnaces for these purposes was not only a matter of earnest thought, but of practical application in the primitive days of the iron and steel industries; and at the present time, in many of the older and isolated plants located among the mountains and valleys, almost in their primeval condition, can be seen in operation boilers attached to metallurgical furnaces. These boilers and furnaces, however, fail greatly to keep pace with the rapid development and requirements of the iron and steel industries which have been so marked for a quarter of a century.

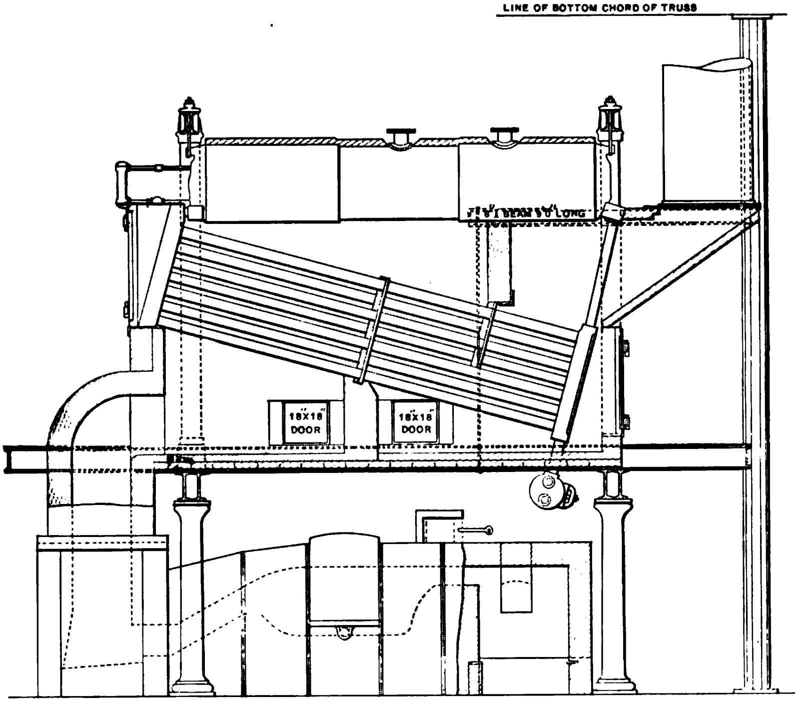


FIG. I.—BABCOCK & WILCOX BOILER OVER PUDDLING FURNACE.

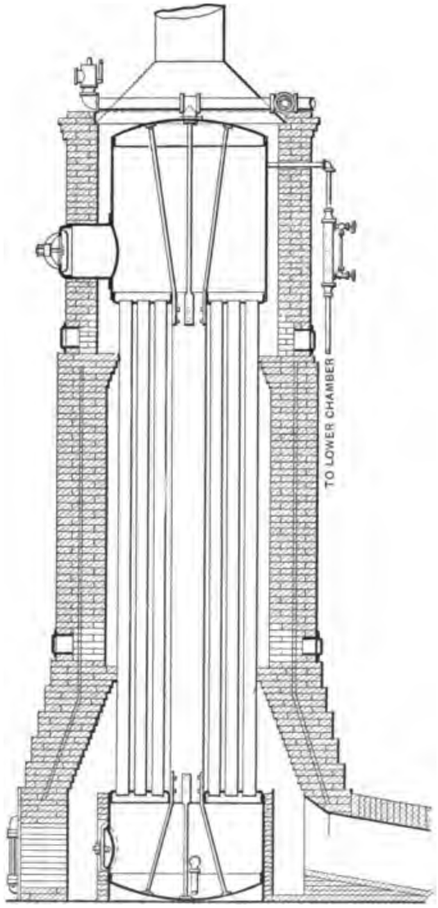
The multiplicity of forms of tubular and water tube boilers that have been in successful operation during the last

ten years has given an incentive to renewed efforts in this line of waste heat utilization. To pass through manufacturing districts, such as Pittsburgh and various points in the Ohio valley, in fact, wherever these industries exist, and see the great volumes of flame emitted from scores of furnaces, has been suggestive to all interested of great waste, well worthy of an attempt to capture and utilize.

Recent developments in this direction are the application of the modern water tube boiler for this purpose. Such an application is shown in Figure 1, which represents a Babcock & Wilcox boiler over a puddling furnace at the Oliver Iron and Steel Company's works. So satisfactory has been the result of its operations as an auxiliary steam force, that others have been placed in operation and are productive of good results. Closely following on the heels of these, a number of Hazelton boilers were similarly arranged, their vertical form being thought specially adapted for reducing the cost of furnace and giving a more direct channel for the hot gases.

The writer was engaged a short time ago in making tests upon a more recent type of boiler, known as the Cook boiler, manufactured by the Aultman & Taylor Machinery Company, of Mansfield, O., and shown in Figure 2. Tests were made of such boilers at Leetonia and Youngstown, O., and in both places gave results of a satisfactory character.

It should be kept constantly in mind in reviewing results of tests of boilers placed under these conditions and for this purpose, that there is a prominent distinction as compared with regular stationary boiler practice, which is often overlooked or ignored by interested parties, and that is, the ordinary or regular boiler is fired for the best economy, and the furnace is constructed solely to give the best steaming results. In the case of boilers placed over heating or puddling furnaces, on the other hand, the firing is done for the purpose of a metallurgical result, and the furnace, similarly, is constructed with this single



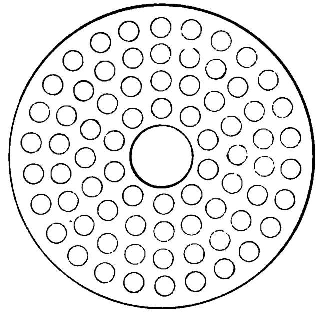


FIG. 2.—VERTICAL AND HORIZONTAL SECTIONS OF THE COOK WATER TUBE BOILER.

object in view; and as far as steam making is concerned, the boiler is entirely ignored by those who do the firing, the only attention paid to it being the maintaining of the water level. Under these circumstances it can readily be seen that an economy test would be not only misleading, but an incongruity. On the other hand, it simply resolves itself into a capacity test, and in a very simple and effective manner. The furnace yielding the regular duty in a metallurgical way, it is a plain proposition that to capture and utilize the waste heat after doing its regular work and before being lost in the atmosphere, is a clear gain, costing nothing in fuel; hence, a boiler so placed and operated,

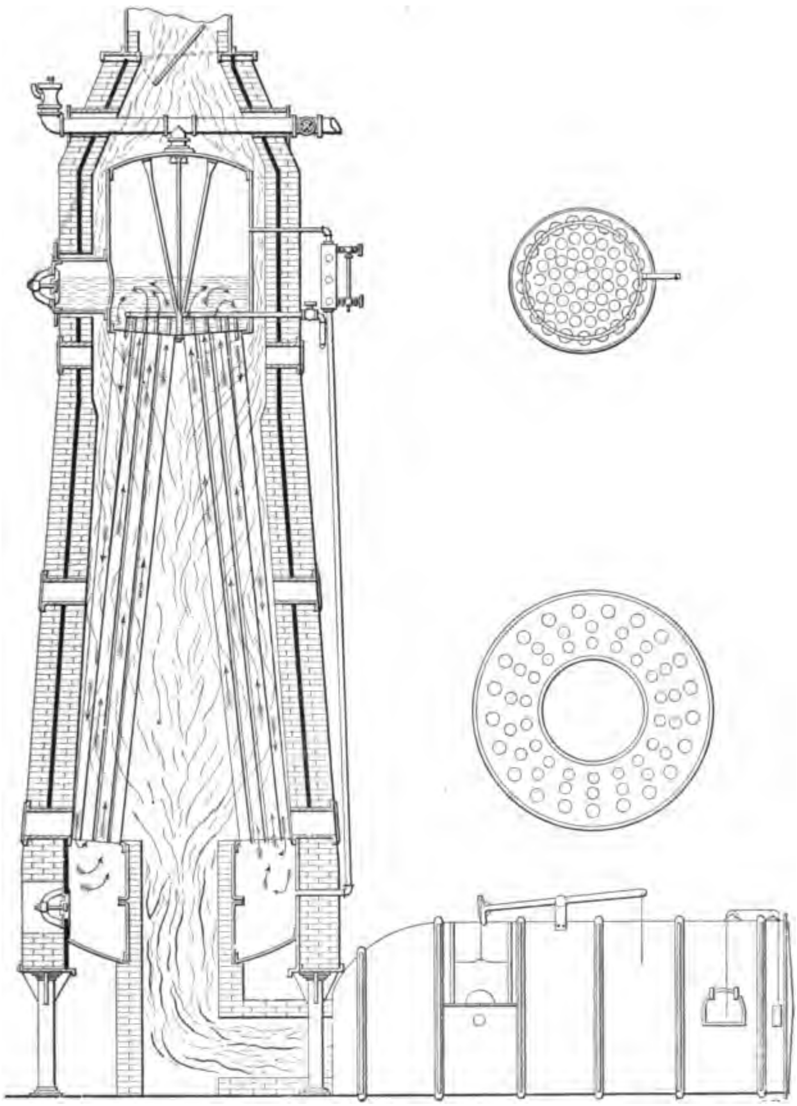


FIG. 3.—SECTIONS OF THE CAHALL WATER TUBE BOILER.

developing 100 horse-power, is a net gain of 100 horse-power capacity.

Boilers thus utilizing the heat of waste gases should not, by any means, furnish the main steam supply. If they did, embarrassment might be caused at times, for the reason, that if heating and puddling furnaces were stopped, the entire plant, wherever motive power was required, would be virtually tied up. The writer's attention was called to just such a case in New Jersey a short time ago. The system of waste heat utilization under boilers should really be an auxiliary to the main steam supply, and where space is valuable, as it always becomes in every plant, it may admit of dispensing with several batteries of boilers at various points. At the same time it eliminates entirely the labor incidental to firing, as the operation of the furnace is completely under the control of the puddlers or heaters.

Since writing the above, I am informed that the Aultman & Taylor Machinery Company have now in course of construction, furnaces so designed, that in case the regular metallurgical process should be suspended, the regular direct firing can be applied in a few minutes. This is an important and valuable adjunct.

In addition to the Cook boiler, the same makers have built and placed in operation one of a similar type, known as the Cahall boiler, the construction of which is shown in Figure 3. In this type the tubes are placed in an angular position. A feature developed in the operation of this boiler has been the thorough dropping of the scale that has formed during operation. Upon cooling, the shrinking of the tubes causes the deposit to loosen and fall into the chamber below, whence it can be easily removed, a feature highly advantageous where impure water is used. A number of these boilers are now doing excellent work over puddling and heating furnaces.

STEAM ENGINES AT THE WORLD'S FAIR.—II.

By Geo. L. Clark.

MAIN ENTRANCE MACHINERY HALL.

The progress made by electricity during the past few years is exemplified at the World's Fair in many ways and places, but nowhere better than in Machinery Hall. Beside the numerous steam engines belted to dynamos, there are various examples of electric generators directly connected and one of these, which attracts much attention, is exhibited by the General Electric Company of New York and Boston. The engine, which was designed under the supervision of J. C. Henderson, the engineer-in-chief of the company, is of triple expansion, direct acting, vertical condensing type, similar to others installed during the last two years by the General Electric Company, with the exception that, instead of piston valves, Corliss valves are used, which are equally, if not more, suitable, as the speed is but 100 revolutions per minute.

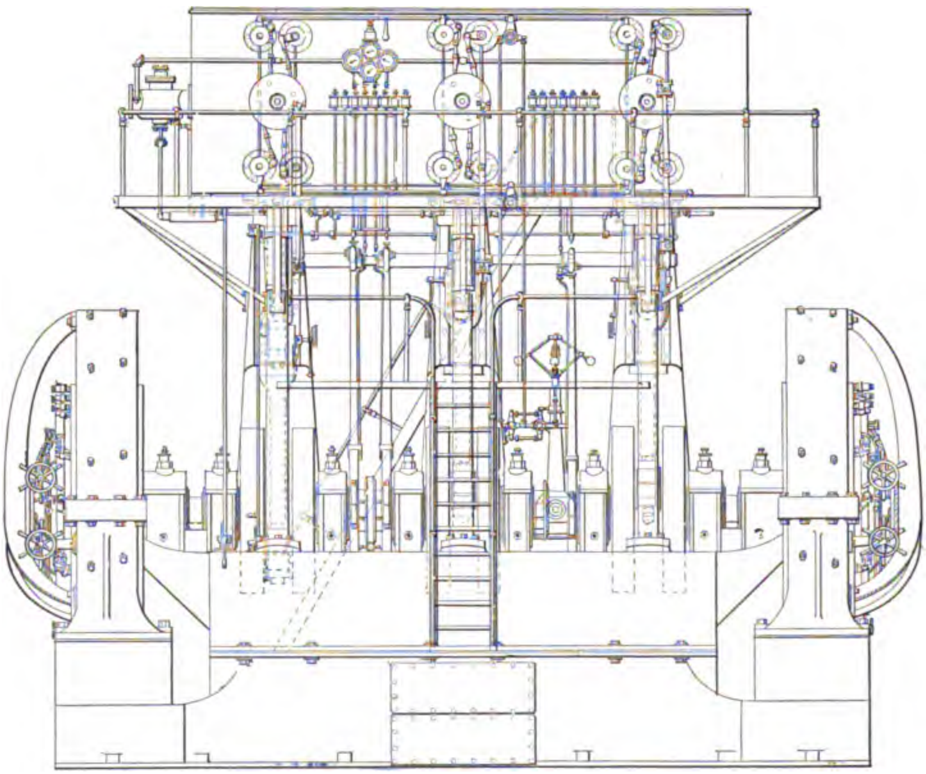
The high-pressure cylinder is 22½ inches in diameter. The intermediate cylinder measures 33⅛ inches, and the low pressure cylinder 55⅜ inches. The stroke of all is thirty-six inches, which, with the stated speed of 100 revolutions per minute, gives a piston speed of 600 feet per minute. At maximum efficiency the number of expansions is 12½, and at maximum power 7½. The initial pressure of steam carried is 160 pounds per square inch, and the condenser maintains a twenty-four inch vacuum.

The chief novelties in the design are, to begin with, found in the fact that the valves are arranged in the top and bottom cylinder heads, thus reducing the percentage of clearance to a minimum. Steam dash-pots are used, located in the heads and easily accessible, and the whole arrangement relieves the front of the engine of the appearance of complication. In the governor is found quite a departure from general practice, this part being made much smaller than is usual and running at a considerably higher speed than is customary, so that a finer adjustment is possible.

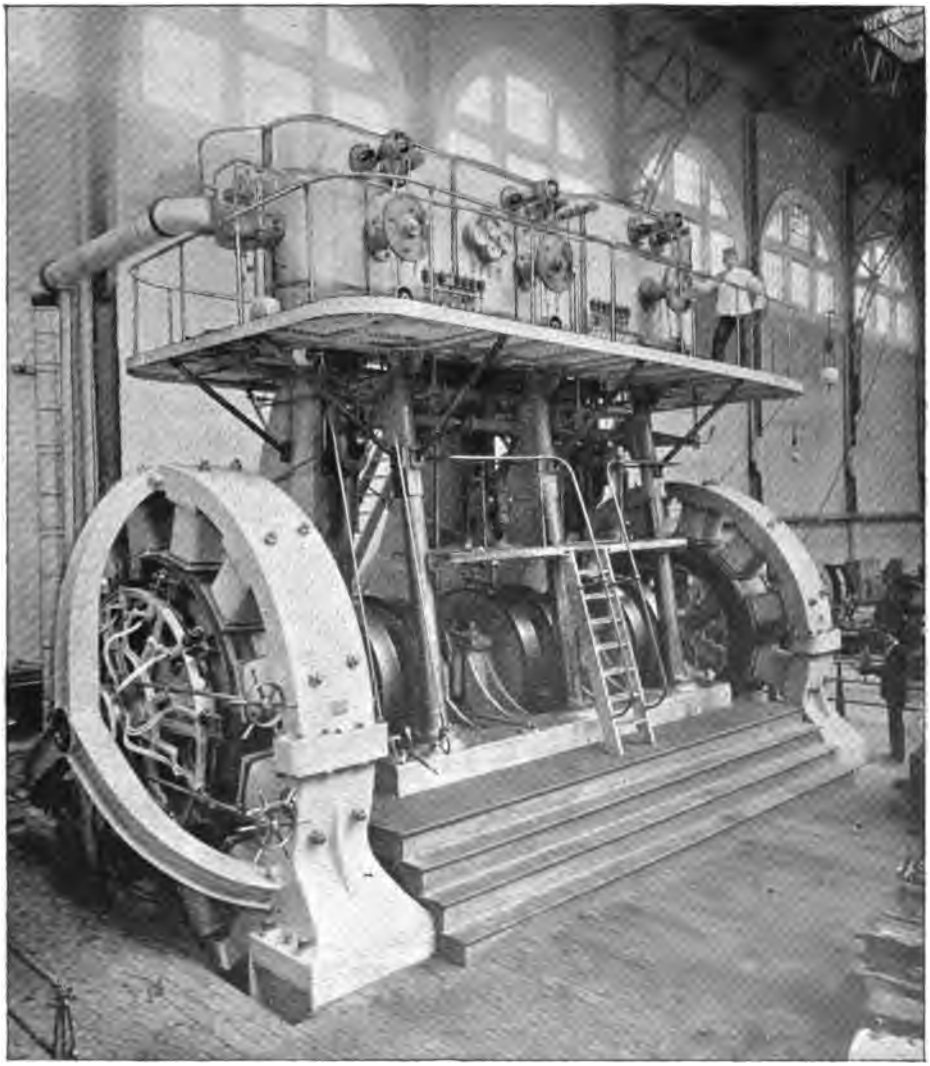
The design was principally intended for operation in stations using the three-wire system with the two dynamos placed on each end of the shaft, thus keeping a constant balance, never allowing the full power of the engine to be transmitted on one side alone. The end bearings are water-jacketed. The armatures are overhung, thus doing away with unnecessary extension of the

bed-plate, liability of breaking shaft, besides making it more easily renewable and reducing the floor space required. The normal output of the generator is 800 kilo-watts, or 5333 ampères at 150 volts, and the maximum output is 920 kilo-watts, or 6133 ampères at 150 volts. The maximum efficiency is 700 kilo-watts, that being the load decided upon as the load of longest duration in actual practice.

The calculated efficiency was eighty-six per cent., but as the smaller generator (the 2 x 200 K. W.), fitted with piston valves did considerably better than figured, it is quite likely that this type will exceed the calculated efficiency in the same ratio. Steadiness of motion is insured by the three-throw crank design and the weight of the armature, which amounts to 39,000 pounds. The surface condenser specially designed for the engine is contained in the foundation box which carries the bed plate as well as the feet of the dynamos. The air and circulating pumps can be worked either direct from the crossheads on the back of the columns, or independent, as in the present instance. The engine is fitted throughout with steam jackets around all cylinders, and outside, between that and the lagging, with magnesia blocks and cement. Katzenstein's metallic packing is used. The total weight of the engine, including that of the condenser and foundation box, is 320,000 pounds. The weight of the two dynamos is 165,200 pounds, bringing the total weight of the whole outfit up to 485,000 pounds. This gives a weight of about 0.6 pounds per watt.



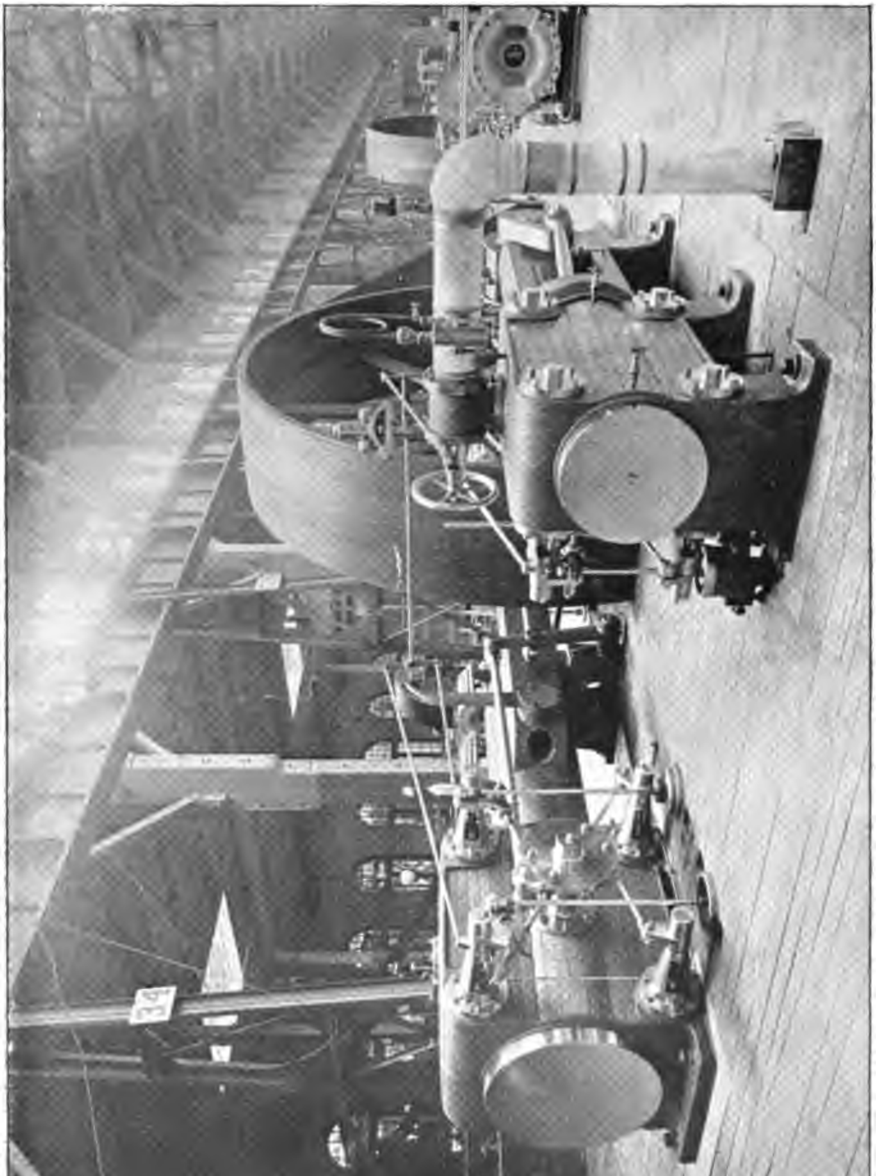
FRONT ELEVATION OF THE TRIPLE EXPANSION ENGINE AND DYNAMOS COMBINED. CONSTRUCTED BY THE GENERAL ELECTRIC CO. OF NEW YORK.



TRIPLE EXPANSION ENGINE AND DYNAMOS COMBINED EXHIBITED BY THE GENERAL ELECTRIC CO., NEW YORK.

The whole design, working drawings, etc., were prepared by the engineering department of the General Electric Company, the builders being the Southwark Foundry and Machine Company of Philadelphia, Pa.

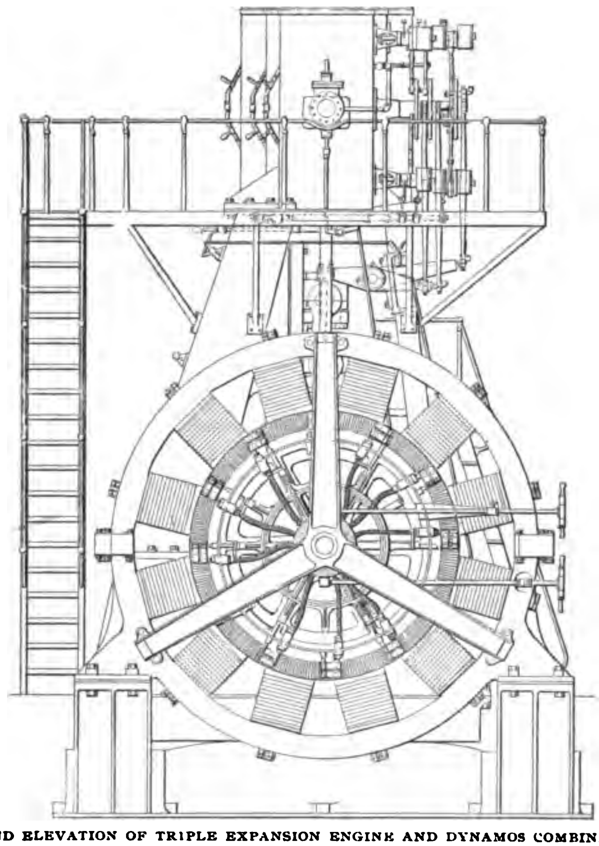
The Stearns Manufacturing Company, of Erie, Pa., show two Woodbury automatic, high speed, tandem-compound condensing engines. The smaller engine has fifteen and twenty-five-inch cylinders, with twenty-inch stroke, and the governor and driving pulleys, one on each side of the engine, are each eighty-eight inches in diameter, and have twenty-three-inch faces. The engine is to run at 200 revolutions per minute, and the indicated horse-power, at maximum economy, will be 375. The maximum load, however, runs up to 500 indicated horse-power. The larger engine, which is exactly the same in design, has nineteen and thirty-one-inch cylinders of



CROSS-COMPOUND ENGINE BUILT BY THE LANE & BODLEY CO., CINCINNATI, OHIO.

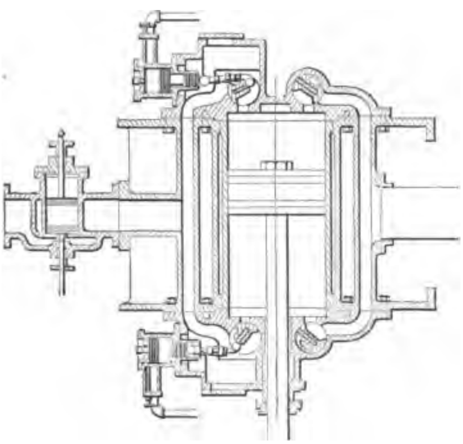
twenty-four inch stroke, and its driving and governor pulleys are 102 inches in diameter with each 31 inch face. The engine will run at a speed of 165 revolutions per minute, and the power for maximum economy will be 600 horse-power, while the maximum load will amount to 800. The two engines weigh respectively 34,000 and 67,500 pounds.

The main features of the high-pressure valve are shown in the accompanying detail illustrations, one of which represents a longitudinal section of the cylinder and valve chest, and the other a horizontal section through the steam chest above the top of the valve. Steam pressure is eliminated from the valve *A*, by the relief-plate *B* on the back, which is supported against steam pressure at top and bottom by a forked or double wedge *C*, whose length is about equal to that of the relief-plate. It is obvious that a longitudinal movement of the wedges inward will force the relief-plate away from valve, and the outward movement of wedges will let it down toward valve. The movement of the wedges, and consequent adjustment of relief-plate, is accomplished by the two adjusting screws, *l*, *l'*, which fit loosely through the cross piece of the wedge and are tapped into the relief-plate. The collars *m*, which form part of adjusting screws, are notched on their peripheries, and a notch is made on the wedge opposite each screw. The collar has 100 notches, and, therefore, admits of a definite degree of adjustment being made, the minimum limit of which is a very minute amount.



END ELEVATION OF TRIPLE EXPANSION ENGINE AND DYNAMOS COMBINED.

The device accomplishes the adjustment of relief-plate to valve in the most satisfactory manner, being at once positive and simple, and while the results of the adjustment can be extremely minute, it is very quickly done, and admits of the valve being steam tight



SECTION OF HIGH PRESSURE CYLINDER AND VALVES OF TRIPLE EXPANSION ENGINE OF GENERAL ELECTRIC CO.

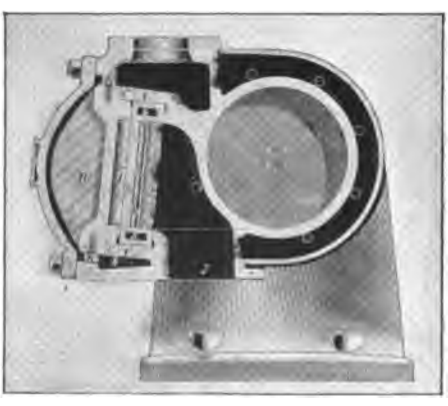
and yet offering little resistance to movement. The movement of the relief-plate in the adjustment is exactly at right angles with the face, or in other words, it is let down equally at all points. The adjustment is made on the inside of the steam chest, and no one can tamper with it from the outside. The passage *k* at the bottom of the chest allows a circulation of steam under the ledge, insuring equal temperatures for ledges *i*, *i'*.

The screw *D*, which is operated from the outside by the handle *E*, is also used as a means of moving the wedges inward and throwing off the relief-plate for a purpose explained below.

The exact amount of inward movement is immaterial, and is regulated by the screw *f*, which forms the stop for the inward movement of the wedges. This screw taps into the relief-plate, and against its head the cross piece of the wedge strikes. When the handle *E* is turned to the left as far as it will go, the wedges are back against collars and are in proper working position. When, on the contrary, the handle is moved to the right, the screw which works through stuffing box forces the wedges inward and throws off the relief-plate. About one-half turn of the handle is all that is necessary. The handle clamps to the stem of screw *D* and is placed in such position that, when down, the wedges are back as far as the adjustment allows them to be drawn, and the relief-plate and valve have their proper working bearing.

The purpose of this handle and screw is not for adjustment, but to afford a means of separating the valve faces from the seats in case they tend to adhere together after engine has been standing over night or longer. This "sticking" of the faces is very liable to occur with any form of balanced valve, unless loosely fitted, and it is very desirable to relieve it, which this device does so that the engine starts with the valve entirely free and the driving mechanism relieved from any abnormal strain. After the parts are thoroughly warmed up, the handle is turned down, or back, as far as it will go.

The faces of valve and relief-plate are at a slight angle from a vertical position, so that they lie in place when steam is off, and afford greater convenience when adjusting inside.

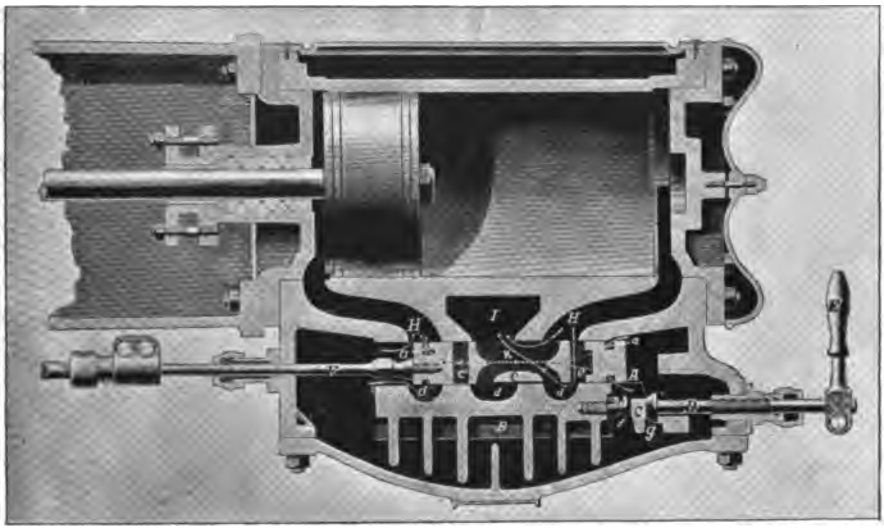


VERTICAL SECTION THROUGH CYLINDER, STEAM CHEST AND VALVE OF THE WOODBURY ENGINE.

In case of over pressure in the cylinder, due to the presence of water, the valve is free to separate from the cylin-

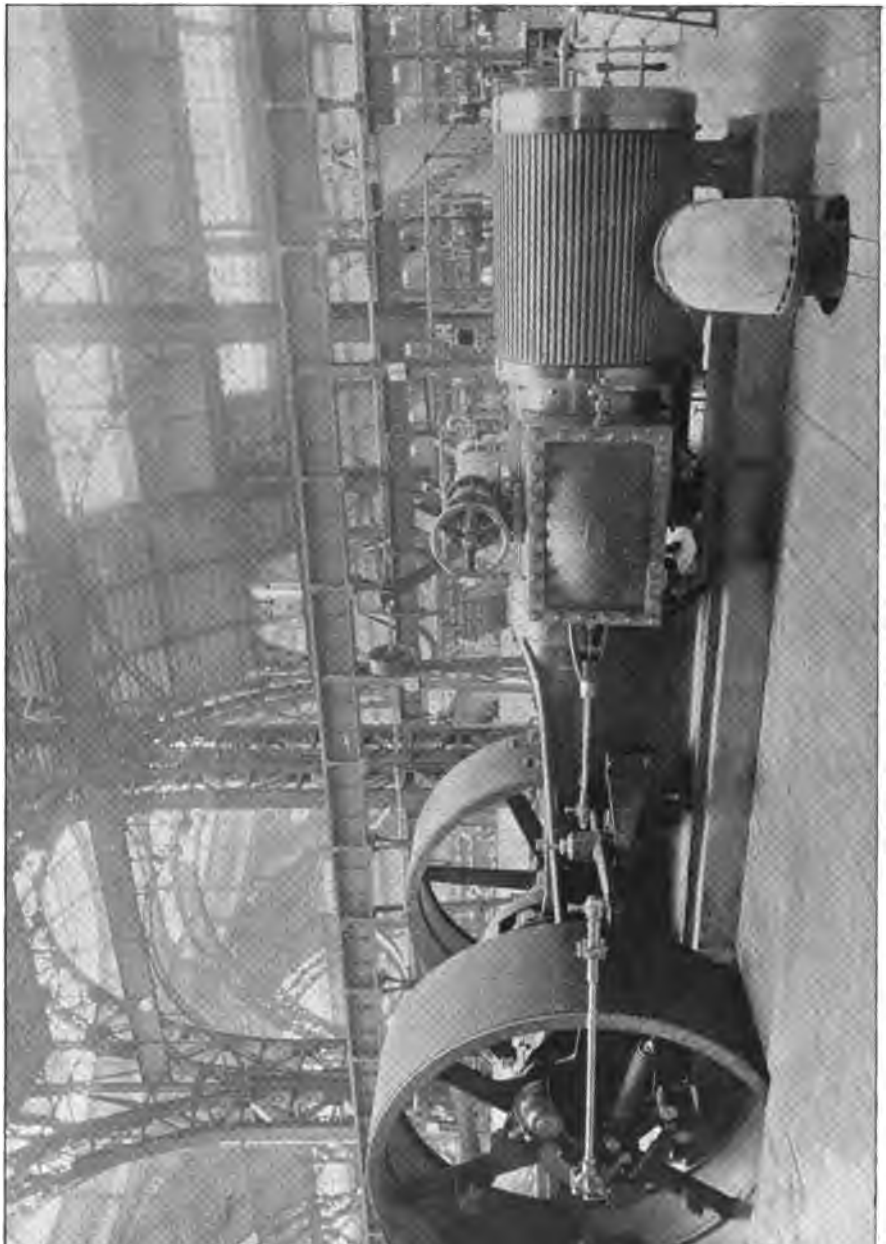
der face and allow the water to be forced into the steam chest and the exhaust port the same as a plain, unbalanced slide valve, with the difference that it takes the relief-plate with it. The danger of accident from water in the cylinder does not, therefore, exist in anything like the degree that it does in engines whose construction does not allow the valve to be forced from its seat under any circumstances.

The means of steam admission and distribution will be understood from the sectional view of the cylinder and valve chest. The valve *A*, besides taking steam at the ends, has supplemental admission ports *a*, *a*, connected at the top and bottom by passages *b*, *b'*, shown in the vertical section of one of the cylinders. In the position of the piston shown the latter is near the crank end. The crank end of the valve is open for admission of steam which enters the cylinder port *H'* past the end of the valve, and also through the cavity *d''* in the relief plate into the port *a*. At the same time steam is entering the supplemental port *a* at the opposite end at two points, and passes through the horizontal passages into the port *a* at the left hand side, and thence into the port H'. Admission, therefore, takes place at four points at the same time, and as the ports are very large a close approach to boiler pressure is effected. Cut-off, of course, is also made at four points simultaneously.



LONGITUDINAL SECTION OF CYLINDER AND VALVE CHEST OF WOODBURY ENGINE.

A double exhaust, too, is used, the valve having supplemental exhaust ports, *c*, *c'*. In the valve position shown, the exhaust steam passes from the cylinder port *H* into the exhaust port *I* in the usual way, and, in addition, passes through the port *c* into the central cavity *K* of the valves, and thence into the exhaust port *I*. This arrangement provides a very large area of exhaust openings, and as the opening is effected very rapidly the pressure drops promptly at release. The plate *e*, forming part of the valve on the relief plate side, serves as a shield to prevent the exhaust steam from impinging on the face of the relief plate and wearing it by attrition so as to cause leaking. This shield does not interfere with the free exit of the exhaust steam, but, on the contrary, assists in guiding the current to the exhaust port *I*. The low pressure valve is the same

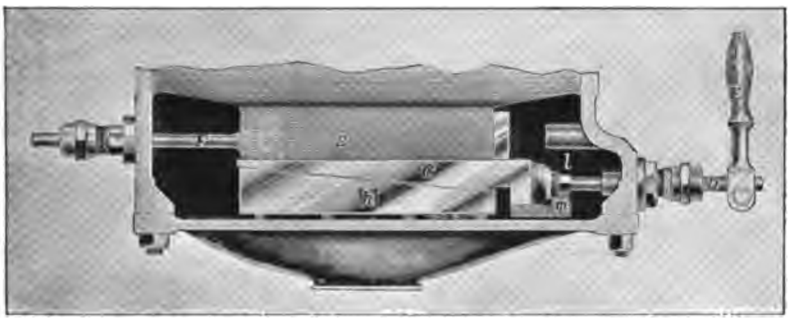


WOODBURY TANDEM COMPOUND ENGINE, BUILT BY THE STEARNS MFG. CO., ERIE, PA.

in all respects as the high pressure valve, except that it is not provided with the supplemental ports *a*, *a*. Both valves are controlled by the governor.

The latter has a bob on the outside instead of an eccentric and its movement is effected by weights whose centrifugal force is counteracted by a single helical spring.

The crank shafts of both engines are solid steel forgings, that is, they are not "built up." The counter weights are bolted to the crank shaft with the regular Woodbury yoke bolts. The detail arrangements of the cylinders are such that all the moving parts of both cylinders can be passed through the low-pressure cylinder, the latter being outside, while the high-pressure cylinder is next to the frame. Thus the pistons, piston rod and inside of both cylinders, can be examined by disconnecting the piston rod from the cross-head and passing the parts out through the low-pressure cylinder without having to break the joint between the two cylinders, or removing either cylinder from its position.

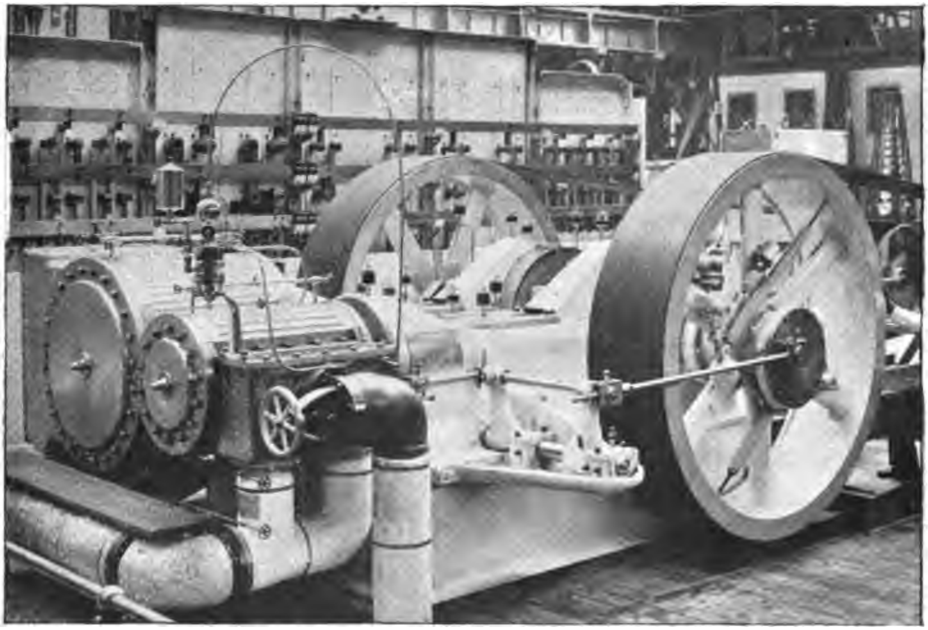


HORIZONTAL SECTION THROUGH STEAM CHEST OF WOODBURY ENGINE.

Before being shipped to the Exposition both engines were set upon cast-iron stands and run to their full speed and given a load of 230 horse-power, during which it was found they were so evenly balanced that the absence of a foundation was only just perceptible. The engines are being used to operate electric power generators. The steam pressure at the throttle is 115 pounds, and the vacuum at the exhaust connection twenty-four inches. The engines are worked in connection with surface condensers.

The Ball Engine Company, of Erie, Pa., show one of their 18 x 36 x 18-inch cross-compound engines. It is designed as a condensing engine, and is capable of running up to from 200 to 250 revolutions per minute with good economy. It is considered to be probably the smallest engine, in proportion to its power, in the Fair, as it occupies a trifle less space than a vertical engine of equal capacity, and has all the advantages of easy access without having to climb stairways or reach galleries to manipulate the various attachments on the engine. The particular work of the engine will be the illumination of the electrical fountains, and in its present situation it is intended to develop from 480 to 500 horse-power with a steam pressure of from 110 to 120 pounds.

The first engines of this type were built by the Ball Company a little over two years ago for the then new electric lighting station of the Edison Electric Illuminating Company of Brooklyn, N. Y. They are specially designed for heavy work, and all the parts are made unusually large and massive. The cranks are opposite each other, one counteracting the effect of the other, so that the engines are well balanced and capable of being run quietly at high speeds. The high



CROSS COMPOUND BALL ENGINE. BUILT BY THE BALL ENGINE CO., ERIE, PA.

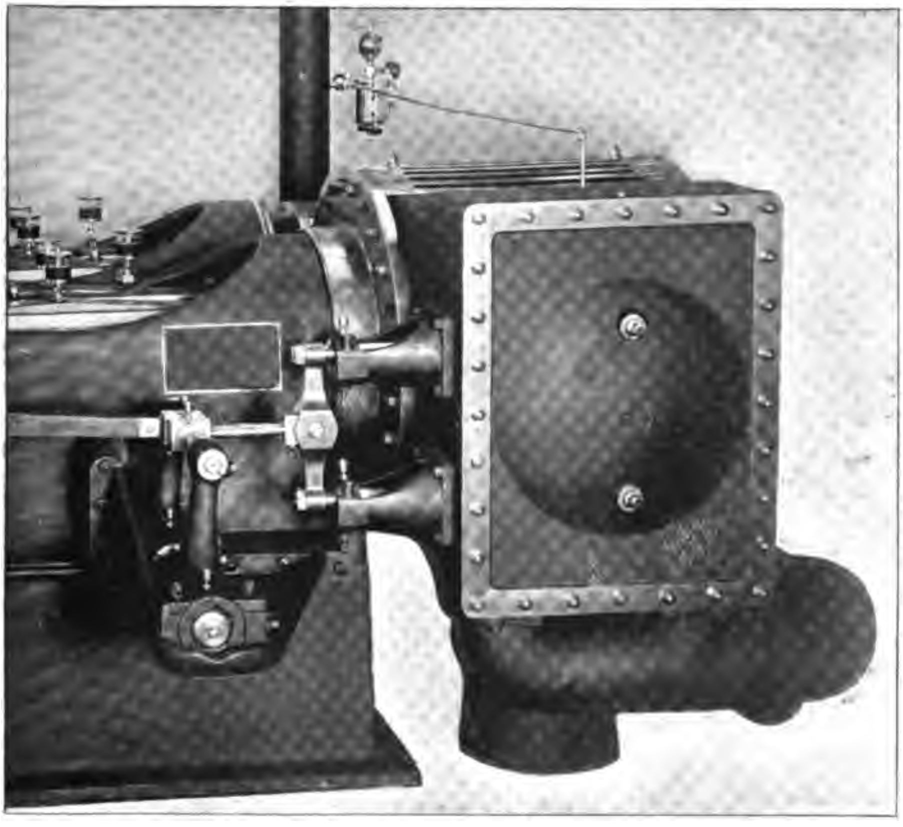
pressure cylinder valve in the engine shown is the same as that used in the company's single cylinder engine, and is illustrated in the accompanying sectional view. The valve consists of two parts, connected in telescopic fashion, allowing each half to adjust itself to its seat. The valve is thus really double-faced. The live steam enters the upper side of the valve, and, being enclosed by the telescopic shells, presses the faces apart with relation to each other, and against the port or passage way surface as shown. By this arrangement there is only sufficient percentage of the whole area of each valve subjected to unbalanced pressure to ensure perfect steam tightness. The combined port areas represent very liberal openings through which the steam passes to each end of the cylinder, thus giving prompt and constant admission up to very nearly the point of actual closure of the valve. The same freedom occurs for the discharge of steam from the cylinder into the chest, and thence to exhaust pipe. The valve is directly controlled by the governor, and constitutes the only automatic cut-off on the engine.

The low-pressure cylinder valve is driven independently by an eccentric which is not influenced by the governor, and hence, is not automatic in its adjustments. It is, however, adjustable by hand so that the point of cut-off in the low-pressure cylinder may be altered to suit different conditions of load. The valve itself is simply a plain slide-valve, well-proportioned, and provided with relief area rings on the back, so that, while very large, giving liberal steam distribution to the cylinder, it works easily and with little expenditure of power. The proportion of the relief area to the total area is such that the valve is very nearly balanced. The valve has two stems connected by a cross piece and driven by one main valve rod, as shown in the view of the low pressure cylinder side of the engine. Both the high and the low-

pressure valves are so arranged that they closely follow up their wear and thus preserve steam tightness.

The crank shaft is made of one solid piece of steel, machined off and key seated to receive the cast-iron counter-balance weights. These are in the shape of discs, which are slipped on the shaft and keyed up solid and tight, after which they are turned oft and polished.

The governor of the engine, as shown, has two weights and two counteracting springs running out from the rim of the governor pulley. In addition to these there is a third spring, attached at one end to one of the weight arms and at the other to the piston rod of a dash-pot, thus providing a yielding base for this spring. The dash-pot consists simply of a cylinder filled with oil, and having a piston with an aperture through which the oil passes as the piston moves in either direction. The spring is arranged for either compression or extension. When motion of the governor weights takes place this supplemental spring is put under tension for the moment and performs the function of giving stability to the governor, but the action of the dash-pot quickly releases the tension and the spring returns to its normal condition, in which it is not a factor in the speed of the engine. The speed is determined entirely by the long springs. The



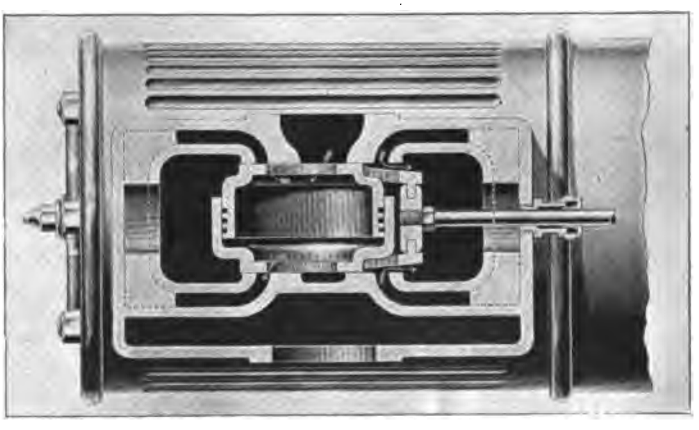
ONE END OF BALL ENGINE, SHOWING LOW PRESSURE CYLINDER AND VALVE RODS.

illustration shows the connection of the weights by means of links to a collar. The latter is supported on an eccentric bolted to the link of the governor wheel which is keyed fast to the shaft. This

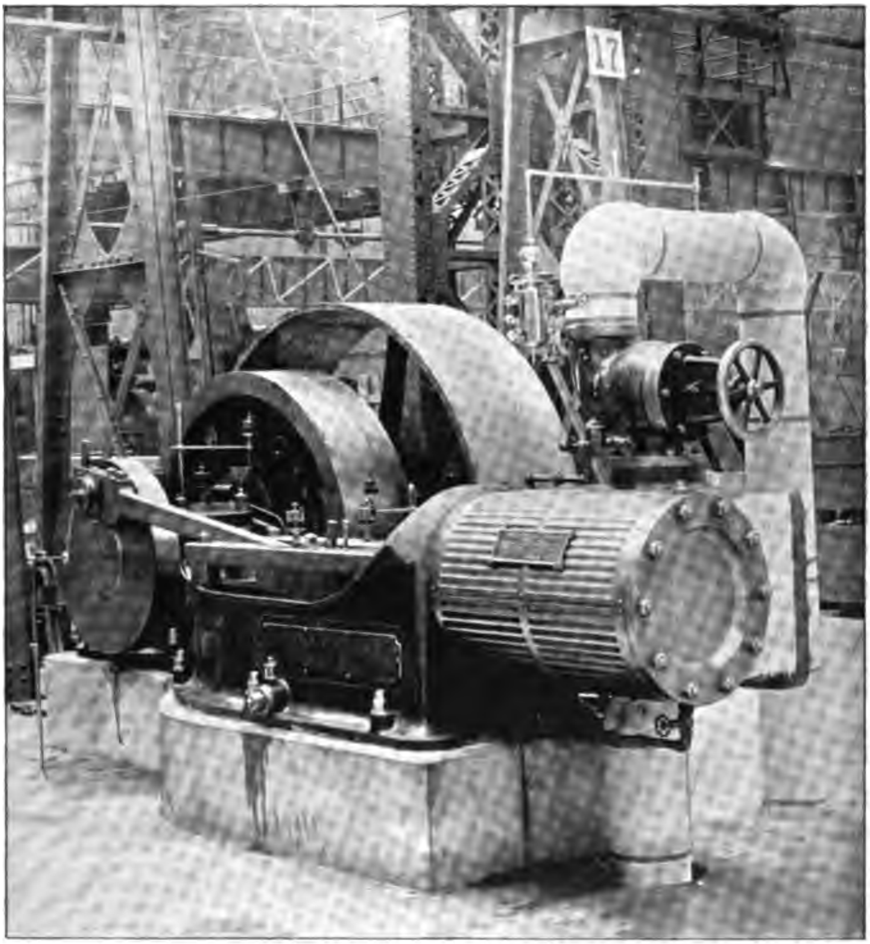
GOVERNING MECHANISM AND SUSPENSION ECCENTRIC OF THE BALL ENGINE.

constitutes a point of suspension upon which the valve driving eccentric is rotated, giving a range of cut-off from ⅝-stroke down to zero.

Two engines—a high speed and a medium speed automatic—are exhibited by the Erie City Iron Works, of Erie, Pa., the latter being shown in this issue. The bed of this engine is of the well-known form first introduced by Tangyes Limited of England, and is a very strong and heavy type, thoroughly ribbed underneath. The bottom slides are separate from and are bolted to the bed. The hood on the back end of the latter forms the front cylinder head of the cylinder, and the stuffing-box is made loose and forced into the head and secured by annular ring nut, which is set up with a spanner from the outside. The cylinder is of the over-hung type, but has double exhaust passages, and the steam ports are placed close to the end of the cylinder, making the live steam passages very short. The cylinder is covered with a cast iron corrugated jacket forming an air space around the cylinder. This can be filled with non-conducting material if preferred. The valve is the well-known Richardson valve, made double, that is with two exhaust cavities, and is held in place on the valve stem by a thick square nut inserted in a pocket cast in the valve, and secured into place on the outside of the valve by two jam nuts. These give a very short hold on the valve, and avoid any trouble by unequal expansion and contraction of the cast iron valve and the steel valve stem, and also effectually prevent this nut from coming loose. The faces of the square nut and the two jam nuts are slightly rounded, so as to allow the



SECTION THROUGH STEAM CHEST AND VALVE OF THE BALL ENGINE.



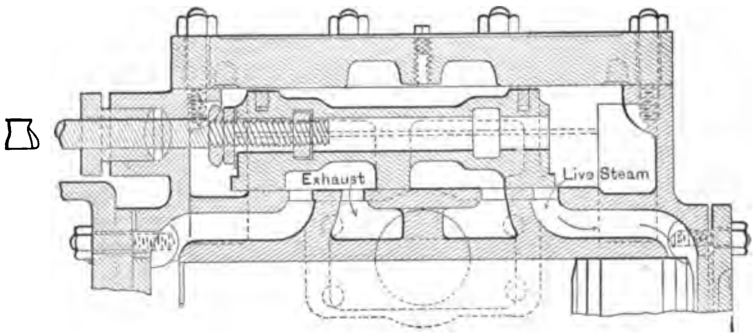
MEDIUM SPEED AUTOMATIC ENGINE, BUILT BY THE ERIE CITY IRON WORKS, ERIE, PA.

valve a slight vertical play on the stem.

The rocker arm is securely keyed to a rock shaft which extends across the whole bottom of the bed, having on the side next to the rocker arm a long taper bearing equal to nearly four diameters of the shaft, and on the opposite end a straight bearing of equal length. The space left for the fit of the rocker arm, is made about one-half of an inch longer than the hub of the arm itself, so as to permit the rocker shaft being drawn through the bed, thereby taking up the wear on the conical end, and allowing the rocker arm to be set further out so as not to change its position with reference to the eccentric and valve rods. The engine has an eighteen by twenty-two inch cylinder and at the speed of 160 turns per minute, at which it is running, develops 250 horse-power.

An engine which will probably appeal particularly to most visitors to the steam engine department, largely because of the rope driving gear with which it is equipped, is that shown by Messrs. Galloways, Limited, of Manchester, England. Rope-driving is essentially English in character, and was probably first used in England in 1863 by Mr. John Ramsbottom in con-

nection with cranes at Crewe. The ropes were of cotton, and measured about ⅝-inches in diameter. They ran over pulleys with V-shaped grooves, having angles of about thirty degrees, and



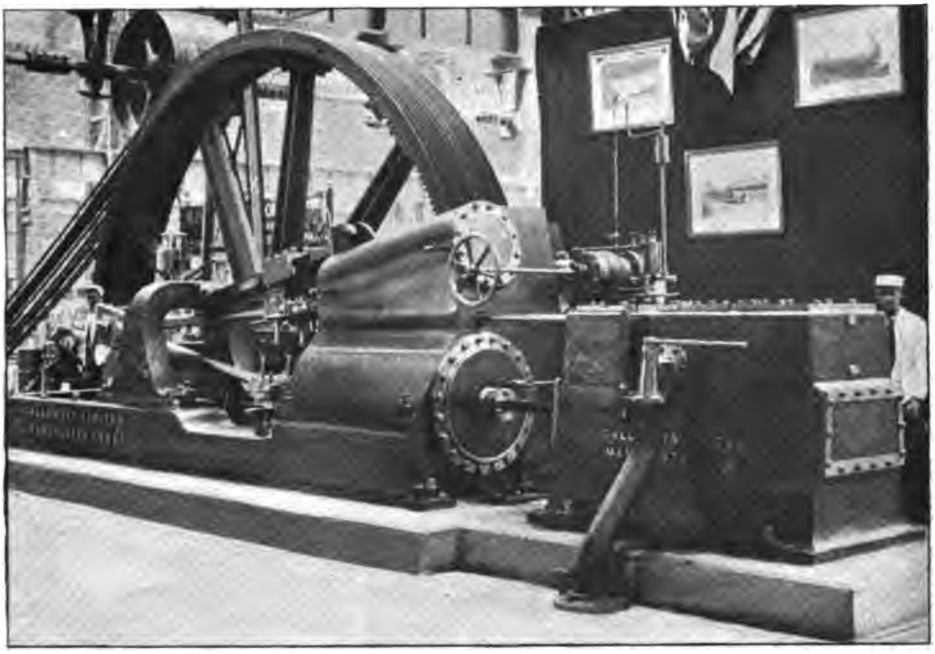
LONGITUDINAL SECTION OF VALVE AND VALVE CHEST OF THE ERIE CITY IRON WORKS ENGINE.

were supported every twelve or fourteen feet by flat pieces of chilled cast-iron. Since this application rope gearing has been superseding belting and other gearing in English establishments, prominent among them cotton mills, and apparently with the most satisfactory results. In this method of driving the surface of the fly-wheel of the engine is provided with a number of parallel grooves for the ropes, the number and size of the latter depending upon the power to be transmitted.

The great advantage of rope gearing over cogs and belts has always been claimed to be the entire freedom from any risk of a breakdown. When a rope shows symptoms of giving way—and ropes always give symptoms ot weakness long before they break—the weak rope can be removed in a few minutes, and another one put in its place. The width of pulleys for ropes is generally rather less than for belts transmitting the same power, but, on the other hand, the grooved pulleys for ropes cost more than plain pulleys. Still, making allowance for this, the total cost of ropes and grooved pulleys for transmitting a given power has been placed at less than half the cost of leather belting and flat pulleys. Notwithstanding these and other advantages claimed, more or less correctly, for rope gearing, Americans still cling to belt transmissions, and a rope-driven plant is now probably as much as it was ten years ago, an object of special interest, if not curiosity, in the United States.

It is perhaps not so strange, therefore, that with all the thousands of horse-power in the Exposition, the Galloways engine should be the only

PARABOLIC GOVERNOR OFTHE GALLOWAYS ENGINE.



COMPOUND ENGINE WITH ROPE DRIVE, BUILT BY GALLOWAYS, LTD., MANCHESTER, ENGLAND.

example of rope transmission shown. The engine is a superposed compound condensing engine of 450 horse-power, and connects with a countershaft with twelve one and three-quarter inch ropes. From the ccuntershaft a thirty-six inch belt leads to a main line of shafting. The main features of the design are clearly apparent in the engraving. The main bed-plate is continuous, embracing at one end the pillow-block carrying the crank shaft neck, and at the opposite end supporting the cylinders. The low-pressure cylinder is attached direct to the bed-plate, and the high-pressure cylinder is placed on and above it at an angle. The distribution of steam to both cylinders is controlled by an arrangement of slide valves, the high-pressure valve being controlled automatically by the governor. The latter is of the high speed, parabolic type clearly shown in the illustration.

The engine transmits its power through two connecting rods directly to one crank pin. The air pump and condenser are arranged on the double-acting system, the air pump being worked by a continuation of the low-pressure piston rod. A very desirable and noteworthy feature of the engine is the safety barring gear with which it is provided and by means of which it may be turned to any convenient position for receiving steam to start it, or by which it may be turned round at any time

BARRING GEAR OF THE GALLOWAYS ENGINE.

when steam is not available. The gear is of very simple design. It consists of a horizontal shaft driven through worm gearing by the donkey engine. This shaft is provided with two helical feathers and carries a pinion rifled for sliding on these feathers.

The pinion is arranged to gear into the toothed ring attached to the inner circumference of the fly-wheel. When the gear is put into operation, the pinion bears against the collar on the end of the shaft and is thus compelled to turn with the shaft, forcing the engine around. When, however, the engine receives steam and begins to turn faster than the pinion on the shaft, the pinion will instantly and automatically slide out of gear. The arrangement, as will be seen, is simple and direct, and entirely overcomes the laborious work of prying over large engines by levers.

Galloways engines of the type shown have been employed successfully for such widely varying kinds of work as dynamo and rolling mill driving, and have found favor in many foreign markets.

(To be continued.)

PROGRESS IN HEATING BY ELECTRICITY.*

By Carl K. MacFadden.

THE fact that an electric current when passing through a resisting conductor will generate heat has been known for years. During the past thirty years it has been applied to an ever increasing extent in the manufacture of heating devices used in almost an unlimited number of ways. It remained, however, for the electric street railway to open up the field for heating. The fact that there has been issued during the past two years and a half over eighty per cent. of the total number of patents on heating devices shows conclusively that the influences which have made themselves felt during the past few years in the general development of electrical apparatus has not left heating behind in the list of improvement.

The first patents issued on electric heaters were taken out in the fifties, and a few years later several were taken out on an oil well heater for melting paraffine and other obstructing material from the bore of oil wells. It appears that, after oil has been flowing from a well for some time, a large accumulation forms at the bottom which, unless removed, will lessen or completely cut off the supply. Nitroglycerine was the agent usually employed to loosen up these deposits, but it would seem that an electric heating device in the form of a pointed elongated cylinder would melt out the obstruction, and that this method was used to some extent in the oil regions of Pennsylvania. Patents taken out between 1860 and 1870 show that the idea of placing an electrical conductor in contact with an insulated heat conductor having a relatively larger radiating surface than the electric conductor had been thought of and applied in a number of ways. In the patent specifications filed between these dates platinum is spoken of as a conductor; it evidently being thought necessary to raise the wire to quite a high temperature, therefore platinum was chosen on account of its high melting point.

There are to-day in the neighborhood of 150 patents on electric heaters, which alone goes to show that considerable attention has been paid them by the inventors. A very large number of these patents apply to the heating of cars. One of the earliest applications for patents on electric heating apparatus, filed in 1869 by Burton, specifies that one of the largest applications of this particular heater for which patent is applied is that of "heating railway carriages by means of heated metallic plates placed under the feet of passengers."

There are a great many inventions, however, that are extremely practical, and as this branch of work progresses, will, no doubt, be brought out and become marketable articles.

To one who has not investigated the remarkable differences in the carrying capacity of a wire when provided with various means of radiating its heat, it will appear astonishing to see a wire carrying safely several times the current that would fuse it in open air. The principle of all well known heaters is that of placing a good heat conductor, having a large radiating surface, in intimate contact with the electric heating conductor; and there is little doubt that, inasmuch as nearly all serviceable heaters depend upon this principle, the advantages of one make

* Paper read before the Chicago Electric Club.

over another will be more in the line of mechanical details of construction than in efficiency. If the heater is made unusually heavy and contains a large amount of heat-conducting material, it will reach its final maximum temperature much slower than one that is built with its heat conductor or reservoir of lighter and thinner material. It may appear immediately after starting both heaters that the latter is not efficient, but if the amount of energy taken up and the radiating surface is the same in both, it will be found that although the heavier heater heats much more slowly than the lighter one, it will hold its heat and remain in a highly heated condition for a longer time after the current is turned off than the lighter heater.

As before mentioned, the electric railway opened up the field for electric heating. The first Sprague road in Richmond, Virginia, was equipped with electric heaters. It has been shown many times that the cost of operating electric heaters on electric roads stands on a par with coal when consideration is made for the value of space that the coal stove generally takes. The electric heaters are generally placed in four or more places in the car where they will be out of the way of passengers when seated, and in such a position that they will at the same time throw their heat into the body of the car. There has been considerable discussion in regard to the amount of current necessary to keep a car warm in cold weather. Reports from roads operating in Northern Michigan and in other portions of the United States and Canada, where the winters are unusually cold, shows that from 1200 to 1500 watts is sufficient current to keep the average sixteen foot car warm in all kinds of weather. It will be seen that inasmuch as the heaters require no attention whatever, and are practically a fixture of the car, the cost of maintaining and operating on the average electric road will be simply the cost of current. Coal stoves take from twenty to forty cents per day to operate if the least account is taken of time used to keep them in heating condition. The coal stove also takes up room for one or more passengers while it remains in the car, which, on a road doing a good business, is a very important item. Coal stoves, too, on cold days, when being heated unusually warm, become so hot that it is often impossible to stand immediately in front of the stove without burning the clothing of the person standing near.

The electric heaters, being placed under the seats out of the way, and furnishing a lower temperature, cannot be objected to on this score, and being entirely out of the way of passengers, and taking up no space in the car which can be utilized to bring in dividend, often saves in a day more than the entire cost of the current furnished them for the day's run.

There are many times in spring and fall when the mornings and evenings are cold and the middle of the day warm, when a heated car for a few hours each day would add greatly to the comfort of passengers. With coal stoves this is often impossible, unless the car can be taken out of service long enough to have a fire rebuilt in the stove. The many testimonials received from the officials in charge of some of the largest roads cannot leave one in doubt as to the way the public appreciates this method of heating.

If we assume that the only cost of running electric heaters is that of the extra amount of coal burned at the power house, there is no opportunity for argument as to the cheapest method of heating electric railway cars, even when not taking into consideration the convenience and gain in car space by the use of electric heaters.

The total cost of one net horsepower at the engine on a plant with an average output of 500 electrical horsepower is about six-tenths of a cent per hour. The cost of an electrical horsepower hour will be found in this same plant to be about one cent. It will be seen from these figures that the total cost of operating electric heaters will be in the neighborhood of two cents per hour.

I believe that it is just as fair to both

sides of the question to assume that the fireman and engineer will not be called on for near as much additional work to furnish current for electric heaters as the street car conductor and other helpers whose time is wholly or partly taken up in attending to coal stoves. In one road which has come under the notice of the writer, a man is paid $1.50 a day to take care of stoves on fourteen cars. This man has no other work to do, with the exception of oiling a few switches near his work. I understand that the man works twelve hours a day, and that the cars run twenty. We may assume that there is at least from ten to fifteen cents a day spent in labor in tending these stoves, the conductor's time not being included. The cost of coal in such a stove will be in the neighborhood of twenty cents when operating twenty hours a day, with coal at $8 per ton. The stove used is open to the same objections that all coal stoves have on electric cars. I assume that electric heaters on these cars could without doubt lower the cost of heating. Under these conditions, as they now stand on this road, the cost of heating during the past winter was far less than in the preceding winter. In many instances coal has to be carried from the power station, or some other point, to the terminus of the line where the cars lay over before starting on their trips. This hauling should be taken in as an item of expense connected with the use of coal stoves.

Street railway companies seldom take account of the cost of operating the two series of incandescent lamps usually found in lighting street railway cars. This lighting takes at least one-third of the energy which might be used for heating.

In a great many estimates which have been made in regard to the cost of coal stoves on electric roads, items have been left out which, when added to the cost of the coal, will bring the actual cost of heating a car on a cold winter day at about the figures to heat the same car by means of electricity. The average life of a street car stove is about three years, and the repairs on even the best make of stoves will be found to amount to a considerable sum before the stove is ready to be abandoned. It also takes time to put these stoves in position and to remove them at the end of the season. It is a well known fact that there are few cars heated by means of stoves that do not have a layer of dust deposited in the car each time the stove is filled or shaken. A deposit of ashes and coal dust five or six times a day on a finely upholstered car soon starts the foundation for an upholsterer's bill, which, of course, on a road equipped with electric heaters, should be a smaller item of expense than on a stove-heated road.

Much has been said in the past in regard to burnouts and other difficulties which occur in the use of electric street car heaters. I believe, however, that with the experience gained in this line by those who have made this branch of work a specialty the failures from such causes as have made trouble in the past will be practically unheard of in the future.

It is by no means an unheard of thing for a coal stove to set barns or cars on fire; a thing which with a properly installed electric heater would be impossible to occur. When properly installed they cannot possibly injure wood-work in the car by excessive heat. There are few street railway companies using stoves for heating that do not find the cost of extra finishing and painting each year, caused by scorched varnish and wood-work around the stovepipe as it leaves the car, to be such as to make quite an additional item to the maintenance of car bodies.

Where power is cheap and coal is dear, which is a condition often met with in mountainous districts supplied with water power, electricity will necessarily play quite a part in heating.

A Pelton water-wheel, when running under a large head of water, such as is met with in the Western mountainous districts, can be harnessed to a little mountain stream and develop enough current to heat and furnish power for a

small factory with practically no cost except attendance and depreciation.

Under such conditions as these electricity could be used to great advantage for heating purposes even quite a distance from the generating station. There are other places in the West where power is guaranteed the year round at $10 per horse-power from turbines. These figures may, of course, be exceptionally low as compared with water power in the Eastern States, and, at the same time, I might say that there are many places in the West where even $10 per horse-power would be considered a high figure, power being obtained the year round at $6 to $9 per horse-power, delivered at the turbine. Many mines in the West are equipped with large water powers, and could use electric heating to great advantage in keeping certain exposed portions of the power plant at a comfortable temperatute. This branch of work has been taken up to some extent already, and, inasmuch as the mine equipped with water power does not depend on coal for its motive power, any coal used for heating would cost even more in the quantities in which it would be purchased than if it was used by the mine for steam generation. In many mines, too, it is out of the question to put in heating apparatus which gives out any gases which might be injurious to the workmen. In the vast majority of cases it is, of course, impossible for this reason to use a coal stove, and entrances to mines and other exposed places in the mines are not heated because it is considered an impossibility.

Since electric heating has been taken up so successfully on electric roads, the fact also presented itself that there would be a large field in cooking devices to be operated by currents of standard voltages to-day used in lighting. A few electric stove companies have at present good lines of cooking utensils which surely fill every want for reliability, cleanliness and good design. There are many cases, especially in the smaller sized cooking utensils, where electricity can compete with coal.

There are, of course, a vast number of plants throughout the country that will not furnish current at a rate which would allow electric cooking apparatus to be used, provided it was simply a question of coal costing so many cents per hour, and electricity a few cents more. There are advantages in the use of electricity for both heating and cooking which must not be ignored. There are a great many places where electric light costs more than gas, and still it is the modern illuminant. It has advantages which gas has not, and the public is not slow to take advantage of them ; and for this reason more than any other there are few towns of any size that do not have their electric lighting plant, even though a gas plant has already been installed.

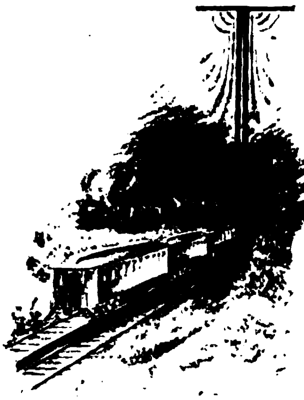
For the heating of chemicals and other applications where an exact amount of heat is needed, electricity possesses more advantages than any other method of heating, and there is no doubt but that in this particular line it will be used to a large extent. For heating water in drug stores, buffets, etc., electricity also should take quite a part. For heating offices and other small rooms in buildings not equipped with steam, electricity, even at current rates for power service, will be found to be far less expensive than one would at first suppose. An office heater capable of warming a fair sized room will be found to be not only an extremely satisfactory way of heating from a sanitary point of view, but will, of course, be entirely free from all gases or odors which are indispensable with the gas or coal stoves.

In conclusion, I would say that the field for electric heating seems to be on the eve of development in a sense that will be a surprise to even those laboring in this branch of work. The general public cannot remain long in ignorance of advantages of this method of heating, and although there will be many places where electric heating is an impossibility from a practical standpoint, there will still remain an immense field in which the electric heater will take a firm and permanent hold.

FAST TRAINS OF ENGLAND AND AMERICA.

By G'r Lodian.

Second Paper.

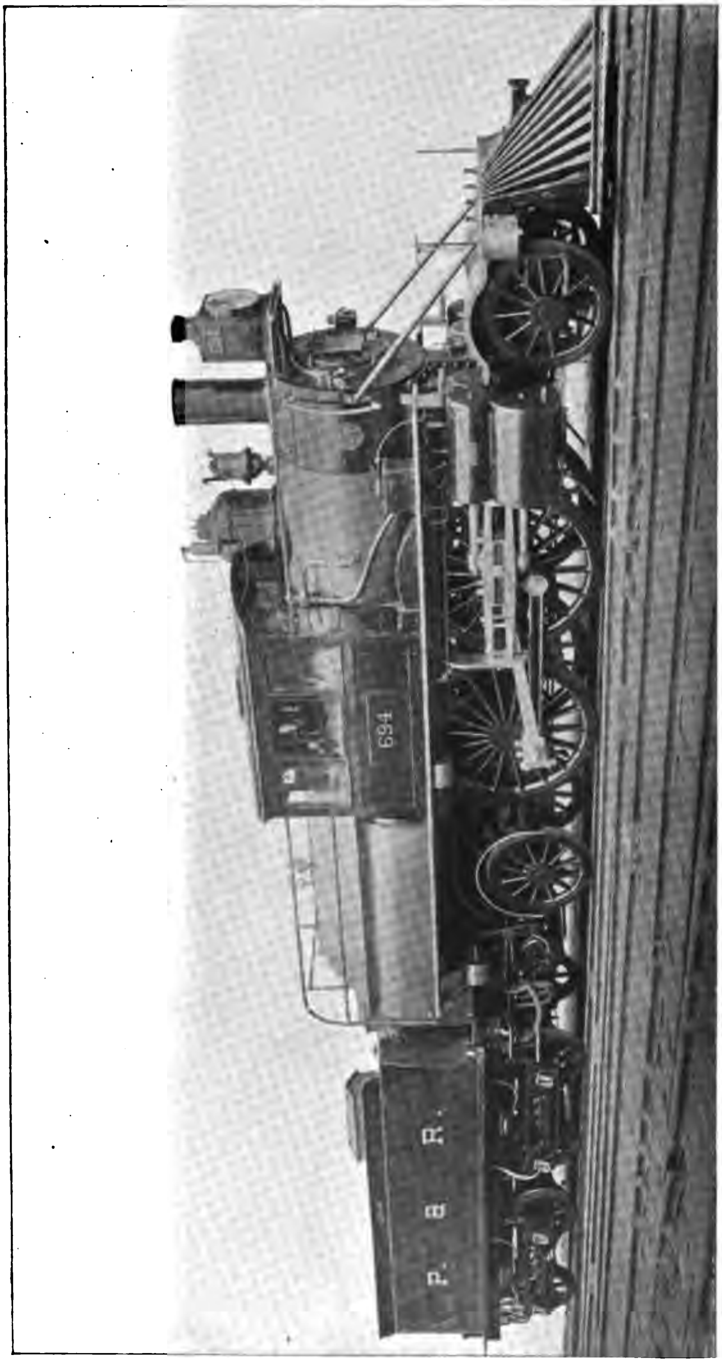


THE most rapid expresses on the Great Western Railway of England are the forenoon and early evening dispatch trains. The run to Swindon, about seventy-seven miles, is covered without a halt in about one hour and twenty-five minutes. The timing and punctuality of a few of the trains is very close. At some of the stations which they pass on the road, these expresses are literally timed to the second in the running time-books—the quarter-minutes being given. Such was the speed nearly fifty years ago on the Great Western, that the west of England expresses performed their journeys in those days within fifteen minutes of the time required nowadays by the "Flying Dutchman." The engine for this train weighs, ready for the run, about 100,000 pounds, of which 40,000 pounds are on the drivers; the boiler pressure is 165 pounds, and the heating surface amounts to 1440 square feet. The cylinders are inside the frames and measure twenty by twenty-four inches. The drivers are seven feet eight inches in diameter.

On the Great Eastern Railway the longest runs are from London to Parkeston-Quay, 69¼ miles, the distance being covered in one hour and forty-five minutes; and from Liverpool street to Ipswich, 68¾ miles, which is traversed in one hour and forty minutes. The highest rate of speed, nearly fifty miles an hour, is attained between Spalding and Lincoln. There is also a good run from London to Cambridge with some sharp curves and heavy grades. The distance is fifty-eight miles, and is passed over in seventy minutes, the running occasionally being done by petroleum-burning locomotives.

The new type of express locomotive on the "London and Southwestern Railway" (W. Adams, engineer) is one used for hauling the United States mails up to London, now that the American line of steamers calls at Southampton. This engine is believed to have the largest bogie platform of any engine in the world, but does not appear to come up to expectations. The proverbial slow-going on the road is seemingly hereditary. It is given out that the run from Waterloo to Southampton, 79¼ miles, is made without stopping, at the rate of 47.55 miles per hour, and the return journey as far as Vauxhall, at the rate of fifty miles an hour, long gradients being encountered. It is doubtful, however, whether this speed is maintained in regular running.

Another good run is that from Waterloo to Christchurch, a distance of 104 miles, which is said to be made without a stop at the rate of forty-six miles an hour. From Waterloo to Salisbury, 83½ miles, a speed of 43½ miles an hour is kept up. From there to Exeter, some heavy grades are passed over, with stretches of one in eighty, and nearly two-thirds of a mile of one in seventy. The train load on these quick runs sometimes exceeds 310 tons, including the weight of engine and

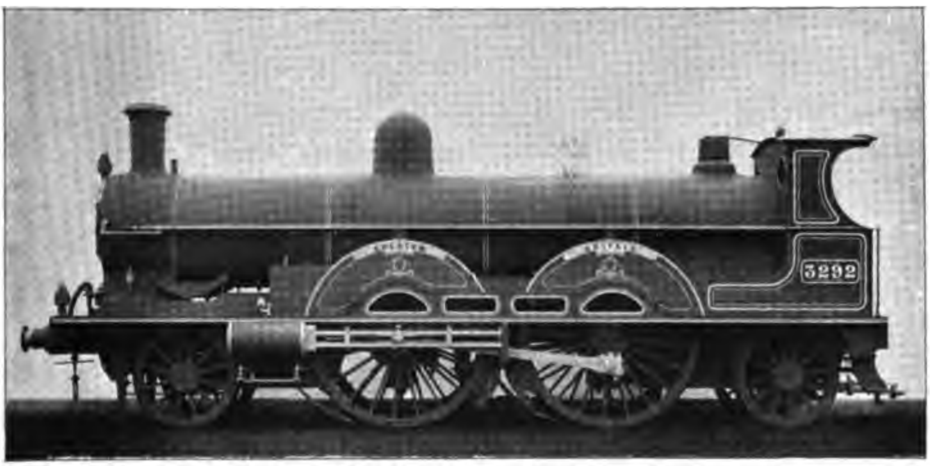


FAST PASSENGER ENGINE ON THE PHILADELPHIA AND READING RAILROAD.

tender. There are ten six-wheeled coaches weighing fifteen tons each, and four coaches of twenty tons, making a net train weight of 230 tons. The four coupled driving wheels are eighty-five inches in diameter. The cylinders are nineteen inches in diameter by twenty-six inch stroke. A boiler pressure of 175 pounds per square inch is carried.

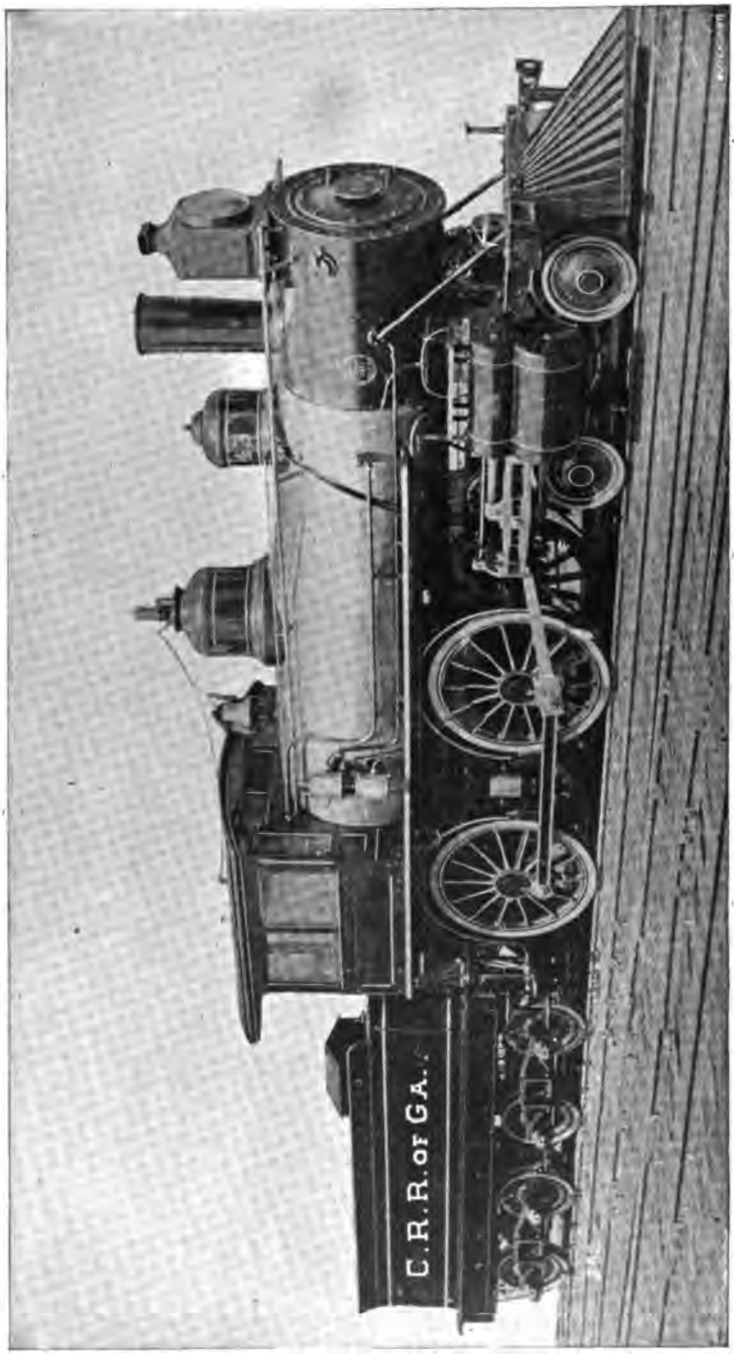
The English Midland Railway, noted for its smooth running, has its longest run from London to Leicester, ninety-nine miles, covering the distance in two hours. Another noteworthy run on this line is from London to Kettering, the seventy-two miles being made in one hour and twenty-five minutes, or at the rate of about fifty miles an hour over an uneven road. The engine is of the eight-wheel type, with 7½ foot drivers. The cylinders are inside and measure nineteen by twenty-six inches.

In Ireland the fastest train is the American mail train which leaves Dublin twice a week for the 177¼ miles run to Queenstown, one engine covering the whole distance. The schedule time is four hours, and there are three stops, two of which are for taking in water. The running time has, however, been reduced to three hours and thirty-one minutes, excluding signal stops and the two stops for water. The load amounts to only twenty-five tons. The engines have 6½ foot drivers, are four-coupled, and have seventeen by twenty-two inch cylinders. They were built at the shops of the Great Southern and Western Railway, at Inchacore, near Dublin, Mr. H. Vatt being the superintendent of motive power. The Great Northern, of Ireland, has its fast-service between Dublin and Belfast. The engine is the regular single driver, seventy-two inches in diameter, hauling four eight-wheeled cars.

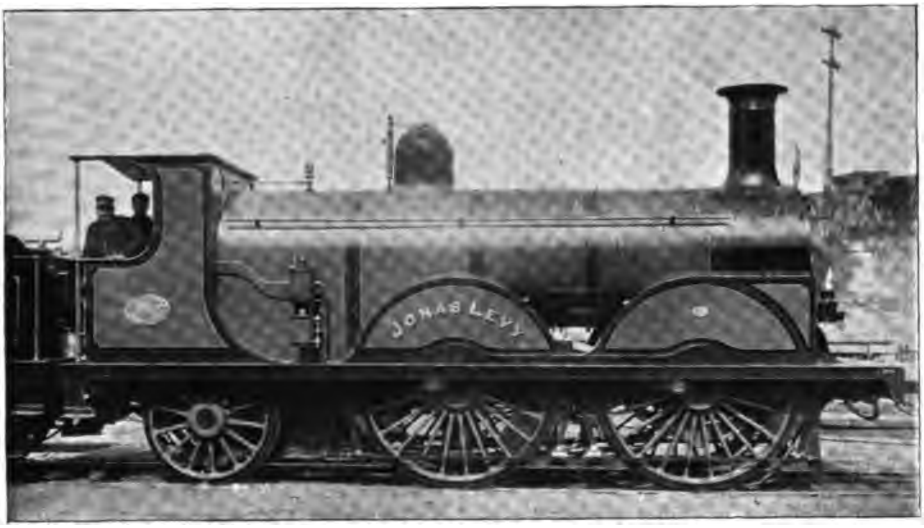


THE "LONG-STOMACH" COMPOUND LOCOMOTIVE ON THE LONDON AND NORTHWESTERN RAILWAY, ENGLAND.

Webb's latest compound locomotive, called "Greater Britain" (or the "long-stomach," as it has been nicknamed along the line), has two pairs of eighty-six-inch, disconnected drivers, and one thirty-inch and two fifteen-inch cylinders, with a common stroke of twenty-four inches. The boiler heating surface amounts to 1505 square feet. There is one pair of trailing wheels. The weight of the engine is 116,704 pounds. The leading pair of drivers is worked from the single low-pressure cylinder which is inside the frames underneath the smoke-box. The second pair is worked from the



EXPRESS ENGINE ON THE CENTRAL RAILROAD OF GEORGIA, HAULING THE FASTEST TRAIN IN THE SOUTH.



EXPRESS PASSENGER ENGINE ON THE LONDON, BRIGHTON AND SOUTH COAST RAILWAY, ENGLAND.

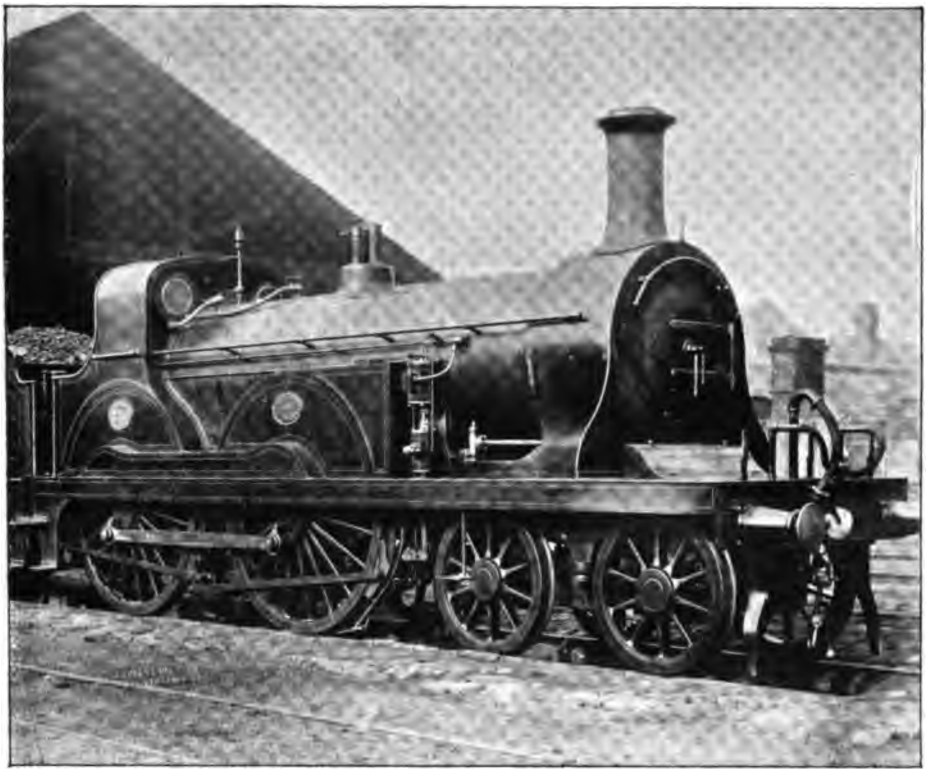
high pressure cylinders which are outside the frames. The coal consumption of the fast compounds ranges from thirty to forty-one pounds per mile. This engine is running on the London and Northwestern Railway, to whose fast trains reference has been made in the previous paper.

That slow-goer of old notoriety, the Southeastern, runs from London to Dover, 74½ miles, without a break, in one hour and forty minutes. The scheduled time claims to do it quicker, but that is only speed on paper. The service is improving, however. Better types of locomotives are being introduced, a good one being the 6½ foot coupled, with forty-two inch truck wheels. The cylinders are eighteen inches by twenty-four inch stroke.

Although in America the South is not particularly noted for high speed trains, the Central Railroad of Georgia can lay claim to the fastest long distance run in "Dixie." The train is known as the "Nancy Hanks," after the celebrated race horse. The run is from Savannah to Atlanta, Ga., a distance of 294 miles, which is made in 400 minutes. Sixteen stops are made, one of them fifteen minutes, and fifteen minutes are also lost in backing in and out of Macon. From Savannah to Macon, 191 miles, takes four hours, and, deducting for stops, leaves the running time practically fifty miles per hour. Many miles, however, are made at the rate of sixty to sixty-five miles. The locomotive used is a Baldwin Compound of the "American" type, Vauclain system, having four outside cylinders.

The Pennsylvania system, with its superb stone ballasted roadbed, has a number of trains whose speed is worthy of note. While many tests of other locomotives have been made, the one illustrated on another page, built at their own shops from their own designs, is the favorite type, and is the engine which hauls their fastest trains. The fastest regular run is from Jersey City to Philadelphia. The ferry from New York leaves at four o'clock, but the train does not depart from the New Jersey terminus till 4.13 P. M. Trenton, 53.4 miles off, is reached in sixty-four minutes, and Germantown Junction, thirty-one miles further, in thirty-six minutes—the eighty-four miles in one hour and forty minutes. The train pulls into the Broad street depot in Philadelphia at 6.05. Other runs on this road which might be mentioned are from Harrisburg to Altoona, 132 miles in three and one-quarter hours, from Altoona to Pittsburgh over heavy

BALTIMORE AND OHIO RAILROAD EXPRESS PASSENGER ENGINE



EXPRESS PASSENGER ENGINE ON THE SOUTHEASTERN RAILWAY, ENGLAND.

grades, 117 miles are covered in three hours and ten minutes. The run from Fort Wayne, Ind., to Arthur avenue, Chicago, is made in four hours, 146 miles, without a stop. One of the Pennsylvania trains covers the distance from Philadelphia to Baltimore, ninety-five miles, in 122 minutes, making one stop.

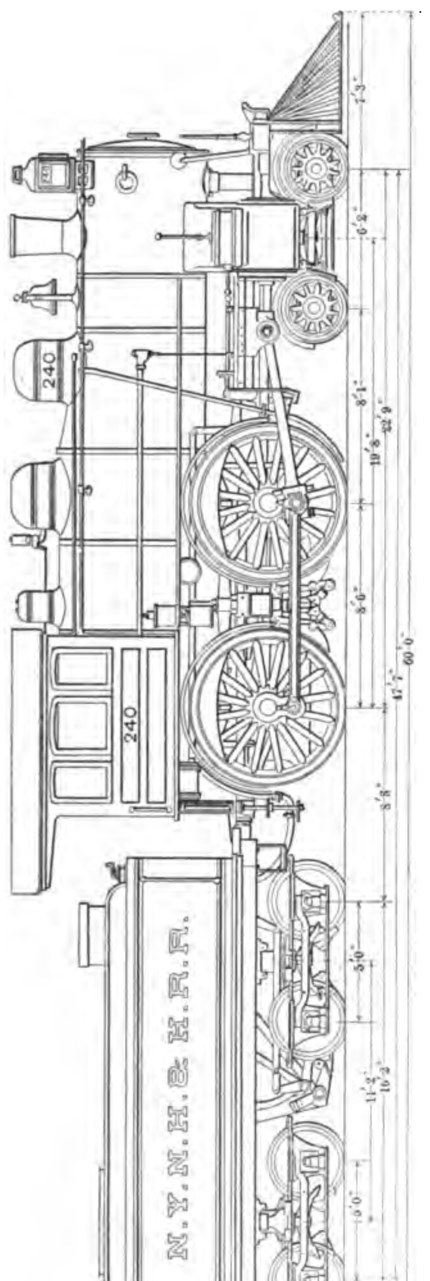
The Baltimore and Ohio, besides the "Royal Blue" train previously mentioned, has a number of trains which cover the short distance of forty miles, between Baltimore to Washington, in forty-five minutes; passengers on the elevated structure in New York city can appreciate this as they ride for one hour to cover eight miles.

For a number of years the New York Central and its great competitor, the Pennsylvania, have both sent limited trains to Chicago covering the distance in about the same time, twenty-four hours. The Central's system is almost free from any grade, but is somewhat longer than that of the Pennsylvania. It has, however, no less than two tracks, and half of the distance four, while the Pennsylvania has but one, for part of the distance west of Pittsburgh. When it was found that the Empire State Express run to Buffalo could be accomplished as regularly as a train running ten to twenty miles slower per hour, the management contemplated a train that would keep up the same rate of speed through to Chicago.

The first of these trains, known as the "Exposition Flyers," left New York on May 28. These trains now leave daily at 3 o'clock from New York, and at 2 o'clock from Chicago, the westbound train being scheduled to make the run in twenty hours, and the eastbound train in twenty hours and fifteen minutes.

At Buffalo the train does not enter

NEW YORK AND CHICAGO TWENTY-HOUR EXPRESS ENGINE ON THE LAKE SHORE AND MICHIGAN SOUTHERN RAILROAD, BUILT BY THE BROOKS LOCOMOTIVE WORKS, DUNKIRK, N. Y.



FIVE-HOUR NEW YORK AND BOSTON EXPRESS TRAIN ENGINE ON THE NEW YORK, NEW HAVEN AND HARTFORD RAILROAD. 20 BY 26 INCH CYLINDERS.

the station, but stops at Seneca street to change engines only, not letting off or taking on passengers there.

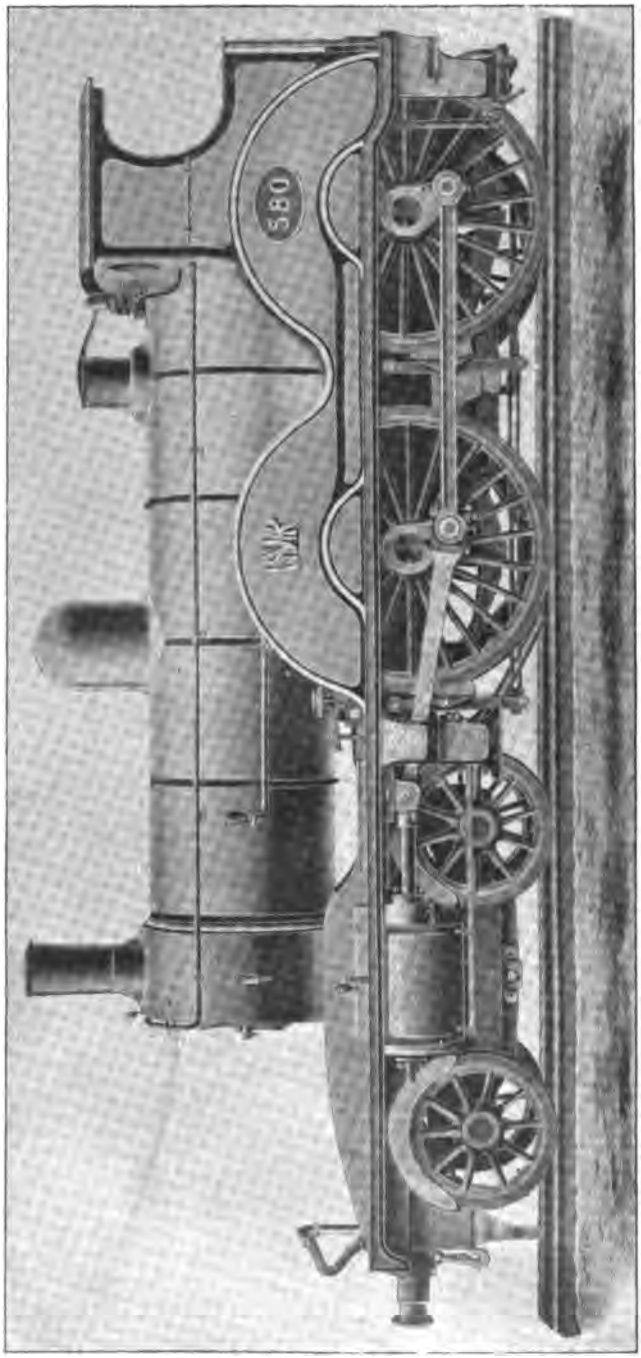
The train runs over the lines of the New York Central and Hudson River and the Lake Shore and Michigan Southern railroads, and makes nine scheduled stops, namely, at Albany, Utica, Syracuse, Rochester, Buffalo, Erie, Cleveland, Toledo and Elkhart. According to the official time table, the train going westward

Leaves			
New York at	3.00 P.M., East. time,		
Albany at	5 50 "	"	143 miles.
Utica at	7.40 "	"	238 "
Syracuse at	8.50 "	"	291 "
Rochester at	10.17 "	"	371 "
Arrives at			
Erie at	12.36 A.M. Cen'l time,		528 "
Cleveland at	2.37 "	"	623 "
Toledo at	4.54 "	"	736 "
Elkhart at	7.42 "	"	869 "
Chicago at	10.00 "	"	980 "

Going eastward the train

Leaves			
Chicago at	2.00 P.M. Cen'l time.		
Elkhart at	4.21 "	"	101 "
Toledo at	7.10 "	"	234 "
Cleveland at	9.27 "	"	357 "
Erie at	11.23 "	"	453 "
Arrives at			
Rochester at	3.45 A M. East. time,		609 "
Syracuse at	5.15 "	"	689 "
Utica at	6.25 "	"	742 "
Albany at	8.15 "	"	887 "
New York at	11.15 "	"	980 "

The engines hauling the train on the New York Central are of the "800 class" already referred to and illustrated in the previous paper. They need not, therefore, be further referred to here. Over the Lake Shore part of the run the trains are hauled by a Brooks engine, of the type shown in an accompanying illustration. The engine belongs to what is known as "class 17 A." The most noticeable feature in which it differs from the other passenger engines on the Lake Shore road, is the size of the driving-wheels, which are six feet in diameter. The cylinders measure seventeen by twenty-four inches, and the weight of the engine in working order is 104,600 pounds. Of this, 33,100 pounds come on the main drivers, and 32,000 pounds on the back drivers. The tender, loaded, weighs 70,000 pounds, thus bringing the weight of

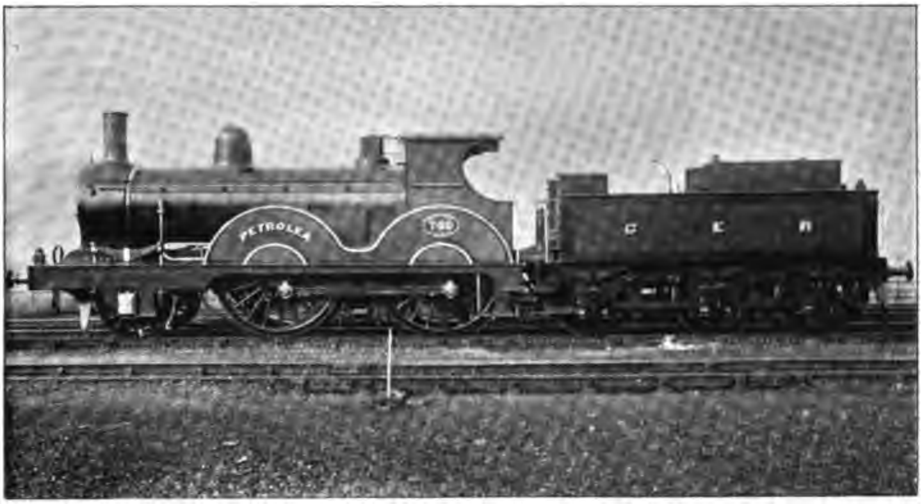


EXPRESS LOCOMOTIVE FOR THE LONDON AND SOUTHWESTERN RAILWAY, BUILT FROM DESIGNS OF W. ADAMS, LOCOMOTIVE SUPERINTENDENT.

engine and tender complete up to 174,600 pounds. A working steam pressure of 180 pounds is carried. The total wheel base of engine and tender is forty-five feet eight inches. The boiler has a total heating surface of 1413 square feet.

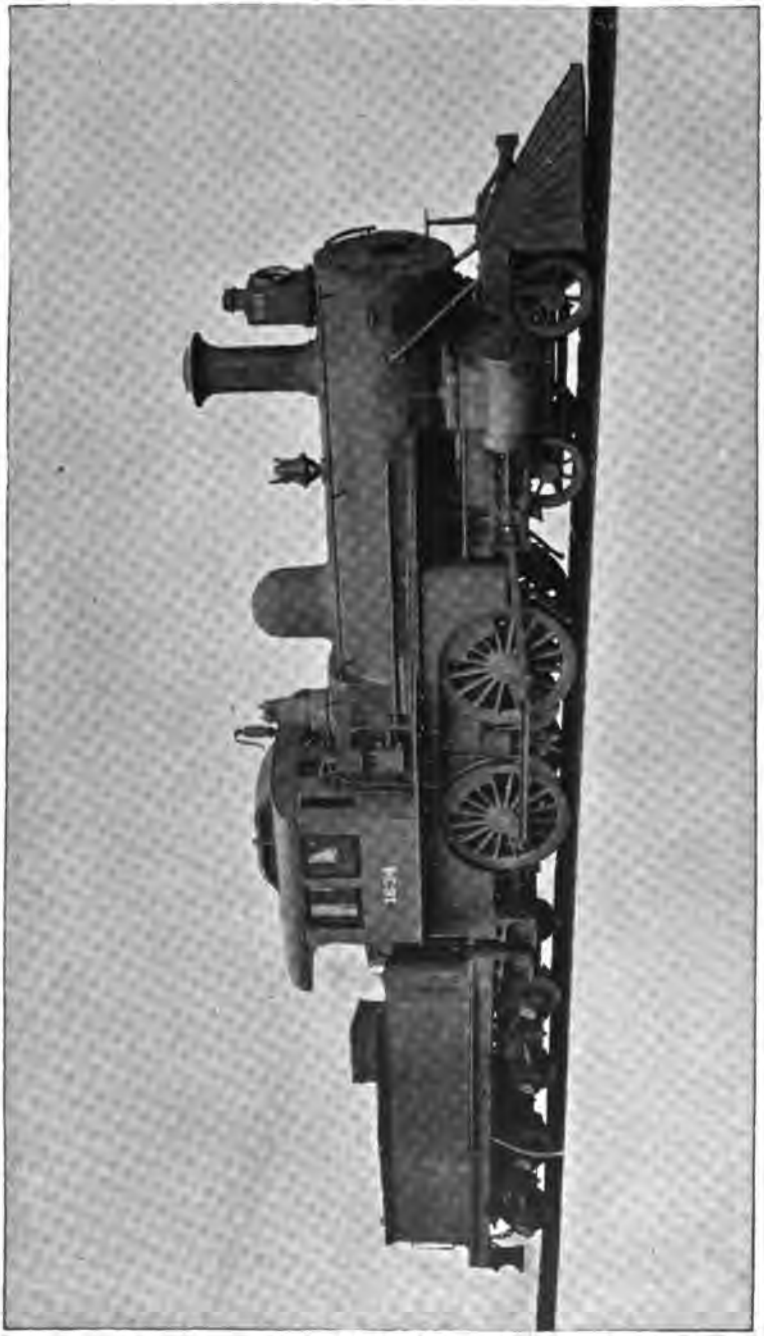
The composition and weight of the train, according to The Railroad Gazette, is as follows, the weights being approximate only: One combination, baggage, buffet and library car, which contains also a barber shop and bathroom; two Wagner cars containing toilet-rooms, staterooms and ten sections each; one Wagner car with sixteen sections. The difference in these cars is in the absence of certain staterooms in the sixteen-section car. The approximate weights of these cars are 85,000 pounds for the combination car and 105,000 pounds each for the Wagner cars.

The cars are fitted with the Gould vestibule and the Leonard platform and hydraulic buffer. This buffer is entirely new, having been first put in use on these cars, and is the invention of Mr. Arthur G. Leonard, private secretary to Mr. H. Walter Webb, third vice-president of the New York Central. The vestibules cover nearly the entire width of the body of the car, lacking but about eight inches of being flush with the sides. The vestibule floor extends out to this width, and consequently the steps hang out beyond the car sides; they are arranged, therefore, to fold up against the vestibule door. This arrangement of the vestibules is remarkably attractive. They are very comfortable places of observation, having large plate-glass windows and floor space enough for camp stools. The buffer is an arrangement of hydraulic plungers equalizing across from one to the other, so that the pressure on the buffers is constant whether the cars are on a straight line or on a curve. These plungers are worked at a pressure of about 500 pounds to the square inch, and in going up and down grades it is found that there is but little change in the pressure recorded. It slacks off ten or fifteen pounds in going up grade, and in going down runs up to perhaps 510 or 515 pounds. The practical outcome of these buffers and vestibules is an extraordinarily stiff and easy-riding train.



PETROLEUM BURNING ENGINE ON THE GREAT EASTERN RAILWAY, ENGLAND.

It is intended to charge passengers on this new train about twenty-five per cent. more than the regular fare. The Central now carries about fifty per



STANDARD PASSENGER ENGINE ON THE PENNSYLVANIA RAILROAD.

cent. of the through passengers from New York to Chicago, although in elegance and comfort there is little choice between its limited trains and those of the Pennsylvania. Were it not, however, for the passengers who stop off at intermediate stations, these through fast express trains would be very unprofitable ventures.

From official reports it is found that the average number of through passengers on all trains to Chicago, both fast and slow, is one hundred and seventy daily. Divided up between the twenty-six through westbound trains it gives an average of eight each. Of the twenty-six through trains, the New York Central runs eight. This new train, however, will undoubtedly carry as many through passengers as it can accommodate between the World's Fair city and New York.

Another remarkably fast train will be that of the New York, New Haven and Hartford Railroad, which will shortly be put on and which will make the run between New York and Boston in five hours. The train will run by way of Providence, and will be the fastest ever run in New England, the average speed being forty-eight and nine-tenths miles an hour, including three stops of five minutes each. Trains will leave New York and Boston simultaneously, at ten o'clock in the morning, and reach their destinations at three in the afternoon, making almost as good time as the "Exposition Flyer" just referred to. The train is scheduled to

Leave New York	at 10.00 A.M.		
" New Haven	" 11.35	"	73.23 miles.
" New London	" 12.43	"	124.20 "
" Providence	" 2.06 P.M.		188.20 "
Arrive Boston	" 3.00	"	232.20 "

West of Chicago probably, the fastest train is on the Chicago, Burlington and Quincy road, running between Denver and Chicago. Train No. 6, eastbound from Denver, makes the run in twenty-nine hours and forty-nine minutes, the distance being 1025 miles. Train No. 1, leaving Chicago daily for Denver, makes the run in thirty hours and fifteen minutes. The engines hauling these trains are of the eight-wheel American type, built by the Rogers Locomotive and Machine Works. They belong to the standard class "M" locomotives of the road, have eighteen by twenty-four-inch cylinders, sixty-nine inch drivers, and weigh, with tender, ready for service, 174,000 pounds. The total weight on the drivers is 65,500 pounds.

Reviewing all the facts presented, it appears that, notwithstanding the great variety in type of locomotives and weights of trains, the running time between various terminals both in England and America, whether the distance be long or short, does not much exceed fifty miles per hour. At the same time it has been demonstrated that a speed of sixty to sixty-five miles is made by many roads daily for part of a run, and as high as 80 to 100 miles for a short stretch on a particularly good piece of roadbed has been accomplished by different types of locomotives. The superiority of any particular type among those illustrated is hard to determine, although for many reasons the locomotives of the "800" class, hauling the Empire State Express on the New York Central road, are capable of pulling a train faster for a long distance than any now in use.

There is no doubt that as regards first-class express trains those in the United States lead in point of speed over long distances, exceeding, say 200 miles. For shorter runs, however, in the neighborhood of 100 miles, the English regular trains still hold the supremacy.

MODERN GAS AND OIL ENGINES.

By Albert Spies, Mem. Am. Soc. M. E.

Fourth Paper.

GAS at a low price, much lower than that at which it is now generally sold by gas companies, is one of the desiderata to which gas engine builders and users alike have been looking forward for some time. It is not that the gas engine, even with the current prices of gas, is by any means unduly expensive in point of fuel, but it is manifest that with cheaper gas the full possibilites of motors of this type would be more readily and widely appreciated, and could be more strikingly emphasized by the probably greatly increased numbers in use. In one of the preceding papers a few figures were given, showing what was actually accomplished with a cheap heating gas in the line of reducing the cost of power in a gas engine. Unfortunately, however, enterprises of the character there mentioned, keeping in view the manufacture and distribution for general consumption of low cost gas for heating purposes, have not yet been pushed to any extent, and users of the larger sizes of gas engines, developing about forty horse-power and more, who have been impressed with, and who decided to profit by, the economies of cheap gas utilization have been obliged to avail themselves of special gas producer outfits to be worked in conjunction with their engines, just as steam boilers ordinarily are operated in connection with steam engines.

This plan of putting in independent gas producers has been specially developed in England, and a comparatively large number of such gas plants on the Dowson system have been built and operated with the most satisfactory results. The outfits, as generally used, consist of a small gas holder and tank with a scrubber placed inside the tank. The scrubber is filled with coke or other suitable material, and the gas, as made, is passed through this before it reaches the holder. A regulator on the gas producer governs the production of gas, within certain limits, by the rise or fall of the holder, and makes large storage capacity unnecessary. In some of the outfits an escape valve has been used on top of the holder to let off gas into the open air or up through a waste pipe when the holder is full, and when the make of gas exceeds the consumption. This, however, has not been employed to any great extent, since the regulator arrangement satisfactorily provides for fluctuations in consumption and avoids the waste of fuel.

The gas is made by forcing a continuous current of steam and air through a coal fire in the producer proper, or generator, so that the necessary high temperature of the fire is maintained while a constant volume of steam is decomposed. The oxygen of the air and steam combines with the carbon, producing carbonic oxide which is rendered still more inflammable by the hydrogen set free by the steam. The total cost of the gas, including wages, etc., and allowing for the increased volume of the gas required to develop the same power as coal gas, has been found, it is stated, to be equal to coal gas at about forty cents per 1000 cubic feet. The result of this certainly very acceptable

price has been, as already intimated, the installation abroad of quite a large number of Dowson producers for private use, and the gradual adoption of gas engines of larger and larger sizes, so that now there remains very little cause for the impression, still entertained by some, that the gas engine is essentially a small power motor. In the United States, combination engine and producer plants are not so well known, or, at least, not so much used, but their advantages are pretty well appreciated, and their more extensive introduction would seem to be a matter of but a few years. Plants of this kind are already in use there in several places, and, from all accounts, seem to be doing satisfactory work. Where they are put in, one is, of course, entirely independent of gas companies, just as in the case of oil engines, the whole outfit being complete in itself.

Careful tests of Otto engines working in conjunction with Dowson producers, as already stated in one of the preceding papers, have shown a fuel consumption as low as 1.2 pounds of coal per indicated horse-power per hour, and Messrs. Crossley Brothers, of Manchester, the English builders of the Otto engine, in the early days of Dowson gas found that the wages of a fireman for several gas generators are not more than those for a set of steam boilers. The gas also can be conveyed with little loss from condensation to various parts of a large establishment using power, and independent gas engines can thus be employed for different lines of shafting. Any department working overtime can have its engine supplied with gas from a single generator, and all the advantages can in this way be secured that are usually claimed for, and achieved by, the system of sub-division of power.

To return, however, from this brief digression to the descriptions of currently used engines, we will present, to begin with, the so-called "Safety Vapor" engine, shown in Fig. 45, and put on the market by the Safety Vapor Engine Company, of New York. A feature at once noticeable in this engine, which also works on the Otto cycle, is the chain or link belt shown at the right, operating the valve. The latter is simply a flat, circular plate with one port cut through it in the shape, nearly, of a sector of a circle. The valve seat is provided with two similarly shaped ports placed close together, one for admission of the charge into the cylinder, and the other for exhaust.

Two ports, exactly the same in shape and similarly located, are provided in the cover plate which holds the valve in position. One of these ports communicates with the exhaust pipe and the other with the gas and air supply pipe. The valve, it will be understood, rotates constantly in one direction and as the port in the valve establishes communication between the first seat port and the corresponding port in the cover plate, exhaust takes place. The valve, proceeding further around, next brings its port over the adjoining admission ports in the seat and cover plate, and the charge of gas and air then enters the cylinder, and is subsequently compressed, ignited, and expanded while the valve completes its revolution until its port again establishes communication between the exhaust ports. This completes one cycle. The valve, of course, makes only one revolution for every two revolutions of the crank-shaft, the large link belt pulley above having twice the diameter of the smaller pulley below which drives it.

The gas goes to the engine through the horizontal branch pipe, shown at the left in the illustration, passes through a graduating gas valve by which the gas supply, and consequently the speed of the engine, can be regulated, and then mixes in a pipe chamber with air taken in through the vertical pipe shown extending downward. The mixture finally enters the admission compartment of the valve chest. Ignition of the charge is effected electrically by a spark passing between two electrodes in the extreme upper end of the cylinder, the current being furnished by an electric battery. Special electric

contact strips are arranged on the valve chest cover and are brought together once in every revolution of the large link belt pulley operating the valve. By this arrangement a spark between the electrodes in the cylinder is produced once in every two revolutions of the crankshaft, or at the beginning of every fourth stroke of the piston.

The engine, as shown in the illustration, is arranged for use in a launch and for this purpose is fitted up with a friction driving gear for the propeller shaft. This gear is similar to the one already described in connection with the Kane electro-vapor launch engine in the April number, and its action will be at once understood from the illustration. There are, as will be observed, two friction wheels, mounted in a frame pivoted on the propeller shaft. The latter carries a third and larger friction wheel, which is in contact with the other two. By means of a lever extending upward, the frame with its two friction wheels, may be thrown over to either one side or the other, bringing the wheels into contact with the rim of either one of the engine fly-wheels and thus causing the propeller shaft to revolve in either direction as desired, driving the launch either ahead or astern. When the friction gear lever is in mid-position, both of the small friction wheels are out of gear, and the engine revolves idly, the propeller shaft being at rest. The stationary engine is exactly similar to the marine engine, except that it is provided with a governor belted to the engine shaft and controlling the main gas valve, either reducing the amount of gas admitted or cutting off the supply altogether when the speed of the engine rises above the normal. The engine is built in sizes of from one-half to six horse-power and, as may have been already gathered from the fact that it can be applied to boat propulsion, is adapted to the use of gasoline as well as gas.

The Rollason gas engine, of which both horizontal and vertical designs are shown in Figs. 46 and 47, is the invention of Arthur Rollason, and has been in use in England for several years with very satisfactory results, the English builders being Messrs. Wells Brothers, of Sandiacre, near Nottingham. It is now also being made in the United States by the Electric

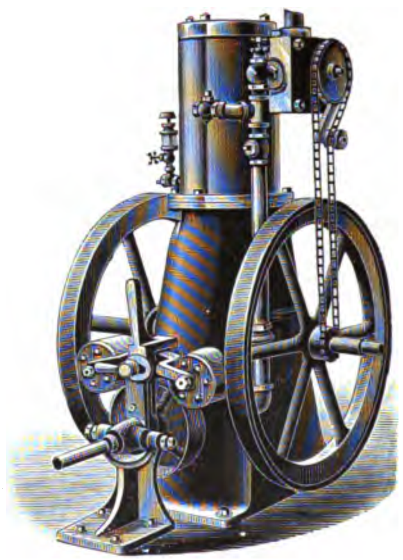


FIG. 45.—THE SAFETY VAPOR ENGINE.

Manufacturing and Gas Engine Company, of Greenbush, N. Y.

When first brought out, the engine was of the three-cycle type, that is to say, there was in ordinary working, one explosion or impulse in every three revolutions or in every six strokes. An explosion having taken place, the piston made a forward stroke under its impulse ; then the exhaust valve was opened, and the piston on its return expelled a large proportion of the products of combustion. During the second forward stroke the piston drew in behind it what was termed a scavenger charge of air which it forced out on the back stroke together with what remained of the burnt gases. On the third outward stroke a combustible charge of gas and air was drawn in, and on the next back stroke, or sixth stroke, this mixture was compressed ready for ignition. This completed the

cycle, and the engine was then ready to again go through the same series of operations. In the engine as now built, however, a four-stroke cycle is followed, and yet the use of the scavenger charge is retained, a feature which is probably not found in any other four-stroke cycle gas or oil engine now on the market. The particular advantage of a scavenger charge of air will be appreciated when it is borne in mind that ordinarily the clearance spaces in a gas engine cylinder are filled with used-up gases when through the valve F in the bed-plate, and gains access to the passage E, one end of which communicates with the pump and the other end with the air valve entering the main cylinder. On the suction stroke of the main piston, air is drawn into the pump, and a gas and air mixture into the cylinder. On the compression stroke the air is compressed in the pump, but only slightly, because the clearance space is so large. On the explosion stroke this air is expanded. As soon as this stroke

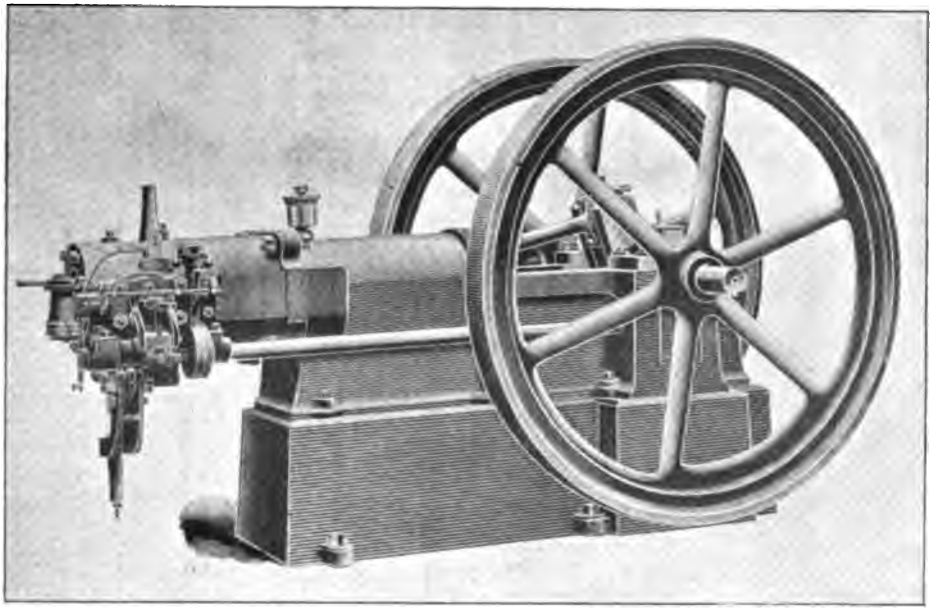


FIG 46.—THE ROLLASON HORIZONTAL GAS ENGINE.

the fresh charge ot explosive mixture enters the cylinder, and these remaining burnt gases probably exert a delaying action on the explosion.

The interior construction of a portion of the Rollason engine is shown in the sectional views Figs. 48 and 49, from which it will be seen that in front of the cylinder is a long tubular guide in which works a second piston rigidly connected to the front. This tubular guide and piston constitute a pump in which air, slightly compressed, forms the scavenger charge. Air enters

is completed, the exhaust valve C opens, and the main piston, returning, sweeps the products of combustion before it, while the pump piston compresses the air. Shortly before the end of this stroke the air valve is opened and allows the compressed charge from the pump to rush into the cylinder and out through the still open exhaust valve. The exhaust valve is kept open until the crank passes the centre, affording ample time for all the products of combustion to be completely swept out. The annular gas valve is

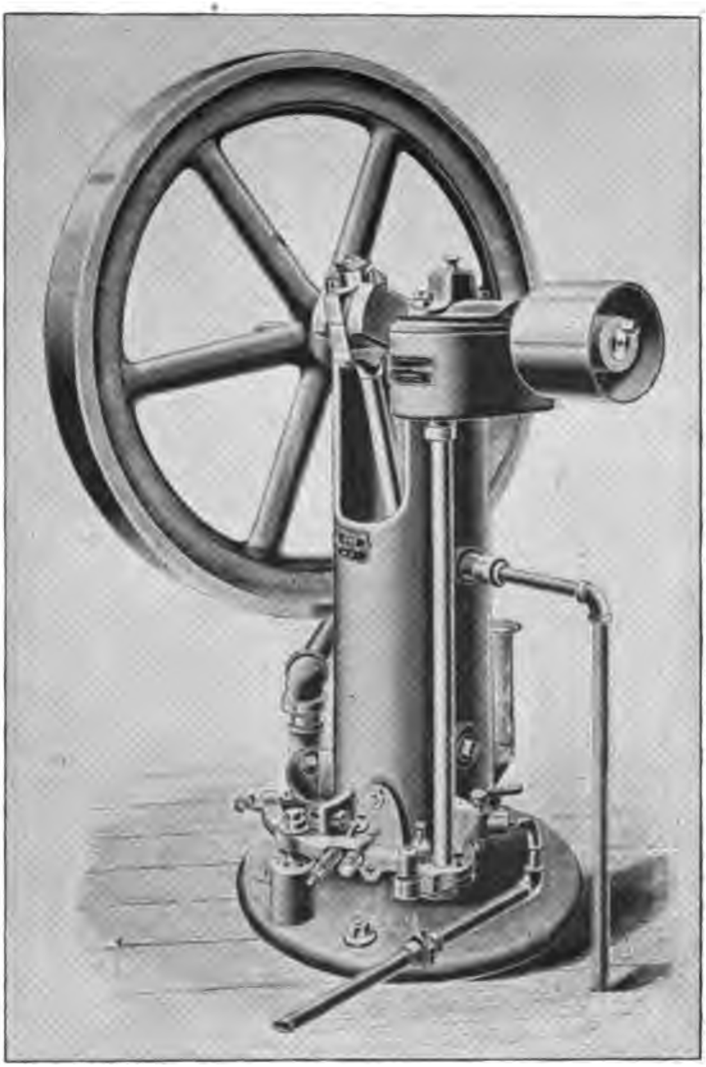


FIG. 47.—THE ROLLASON VERTICAL GAS ENGINE.

then opened and the motor piston draws in its charge.

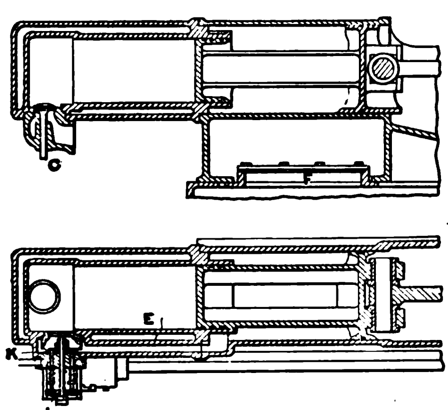
The regulation of speed in the large engines is effected in two different ways. There is a centrifugal governor connected with a throttle valve, and small variations of load are met by reducing the strength of the charge. If the speed is greatly increased, however, the gas valve is not opened at all. It is worked by a hit-and-miss device, and at high speeds a cam connected to the governor trips the device and cuts off the gas.

The admission and exhaust valves are of the poppet type, and the original slide-valve design has been abandoned as in most other makes of gas engine. Firing of the charge is effected by a tube igniter.

The nature of the valve gear will be made clear by an examination of Fig. 50, which represents a cross-section o

the cylinder and of the valve chambers. The explosion or combustion chamber A is surrounded with the usual water jacket and has the passage *a* through which air enters on its way to the air admission ports *b*. The lay-shaft B is driven from the crank shaft by reducing gearing and is provided with a cam, C, for operating the igniting device, and with a second cam, D, for governing the admission valve E and exhaust valve F through the intervention of a two-armed rocking lever pivoted at G. This lever carries at one end a roller, H, which is kept pressed against the cam D by means of the spring J. When the cam D forces the roller H outward, the opposite end of the rocking lever strikes the stem of the exhaust valve F and lifts this valve from its seat, at the same time enabling the admission valve E to close under the influence of the spring with which it is provided. Thus the movement of the lever in one direction under the action of the roller H opens the admission valve, and the return movement under the influence of the spring J opens the exhaust valve, the latter also being fitted with a spring, as shown.

The admission chamber, as already



FIGS. 48–49.—SECTIONAL VIEWS OF THE ROLLASON ENGINE.

stated, is provided with air ports *b* which communicate with the external air through the passages *a*. The gas chamber K, on the other hand, communicates with the source of gas supply and has small ports governed by a lift valve, *c*. Let us suppose now that an explosive charge of gas and air is being compressed in the cylinder end

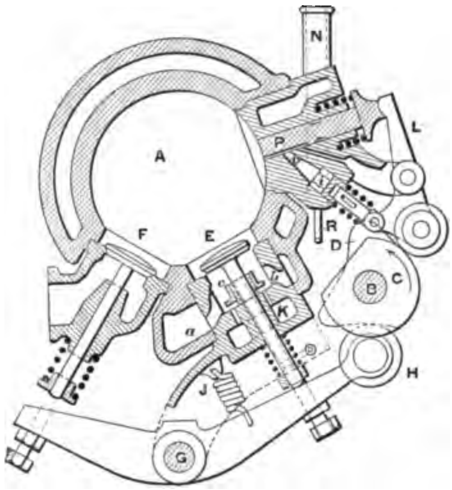


FIG. 50.—VALVE GEAR DETAIL OF ROLLASON ENGINE.

A. A small portion of the compressed charge will escape through a narrow groove into the port *v*, and pass from there through the port *i* into the chimney N, where it is ignited by the gas flame from R. The flame of the ignited mixture passes back into the port *v*, but the fineness of the groove *m* prevents it from passing into the cylinder end A. When the time of igniting the charge in the cylinder has arrived, the cam C permits a quick outward movement of the piston valve P, first closing the port *i* by a small valve controlling it, and afterward opening the small end of the port *v* by the completion of the out-stroke of the piston valve P. The flame is thus first shut in, and then put in free communication with the combustion chamber A, effecting ignition of the charge. The pressure in the combustion chamber, acting through the piston-valve P upon the three-armed rocking lever L, tends to keep the valve which controls the opening *i* tight upon its seat.

For starting large engines, the ar-

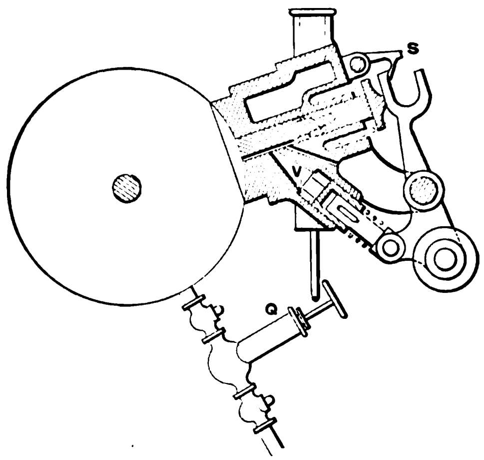


FIG. 51.—DETAIL OF STARTING GEAR FOR LARGE ROLLASON ENGINES.

rangement shown in Fig. 51 is used. A separate hand pump Q, is connected with the gas supply pipe, provided with check valves, so that a sufficient quantity of gas may be pumped into the combustion chamber to form an explosive mixture. To effect ignition of this mixture, the igniting device is provided with a releasable catch, S, Fig. 51, to hold it in the non-igniting position after the crank has turned the centre. If the mixture be burning in the passageway *v*, the release of the catch S will cause ignition and explosion of the contents of the engine cylinder.

In the smaller sizes of engine, the vertical engine, for example, the special igniting valve is not used, and the two-armed rocking lever controls simply the admission and exhaust valves, the tube igniter being always in direct communication with the end of the engine cylinder. The engine shown in Fig. 56 is one of two indicated horse-power. The horizontal design is turned out in sizes to meet the demand.

An example of what is being done in Germany in the way of petroleum engines is afforded by the Capitaine engine shown in elevation and vertical section in Figs. 54 and 55. This engine is now being introduced into England by Mr. L. Tolch, of Liverpool.

The engine works on the Otto cycle. Oil is taken through a pump at K, Fig. 54, and is forced into the vaporizer D, Fig. 55. This vaporizer is kept hot by a flame from the lamp C. The latter is provided with a long tube which bends back upon itself, and ends in a burner cone. The flame plays on the lamp tube as well as on the vaporizer, and in this way the pretroleum is converted into vapor before it reaches the burner cone. The ignition tube F also stands in the flame, and is made incandescent for the purpose of firing the charge, which is compressed within it on the second stroke of the piston. In the latest form of the engine, however, the use of the ignition tube has been abandoned, and the charge is fired by the heat of the vaporizer alone. On the first stroke of the piston air enters through the pipe B and inlet valve A, while the contents of the vaporizer are

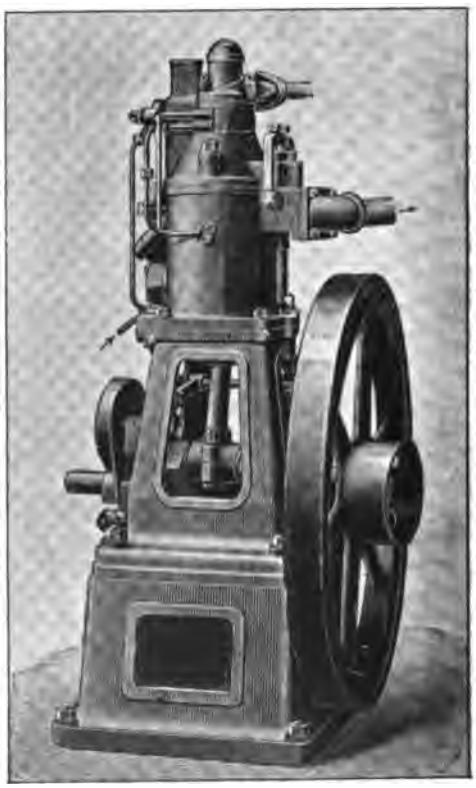


FIG. 52.—THE CAPITAINE OIL ENGINE.

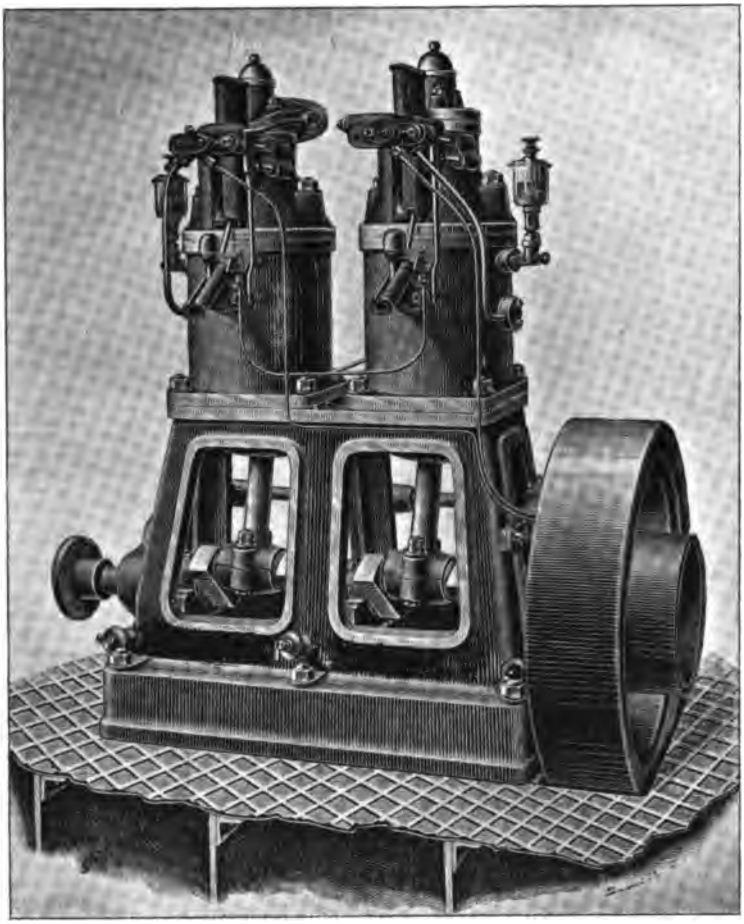


FIG 53.—DOUBLE-CYLINDER CAPITAINE LAUNCH ENGINE.

drawn out by admitting air at its end through the valve C.

The exhaust valve and the oil pump are both operated by an eccentric. As they are required to move only at each alternate revolution, the mechanism shown in Fig. 56 is introduced to throw the eccentric rod in and out of engagement. The eccentric rod is pivoted to a slipper working in a guide ; to this slipper is pivoted a cross-piece S with two arms. These arms work in conjunction with two fixed shoulder pieces striking them in succession. If with the parts in the position shown, the cross-piece were to rise it would operate the bell-crank M. As it neared the end of its travel one of the arms would strike the right-hand shoulder, tilting the cross-piece, so that on its next stroke it would miss the bell-crank. The left shoulder piece could then restore the cross-piece to its old position, and on the next stroke the bell-crank would be moved.

The bell-crank M works the lever L, one member of which raises the exhaust valve O, Fig. 55, while the other operates the pump, Figs. 54 and 57. The oil enters the tube at V by natural pressure, and through the small aperture at the bottom of the bucket S ascends up to the non-return valve H. On pressing the pump rod W upward,

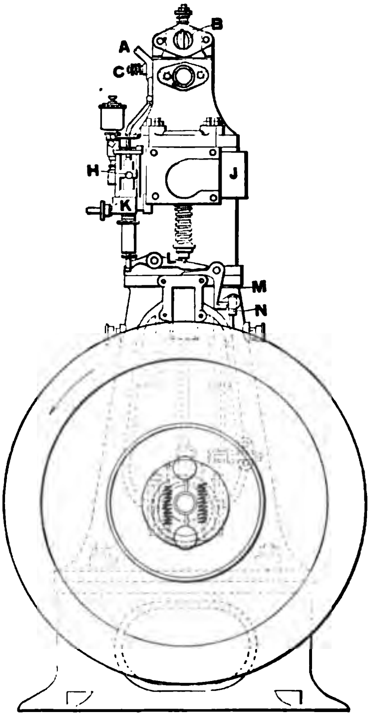


FIG. 54.—ELEVATION OF THE CAPITAINE ENGINE.

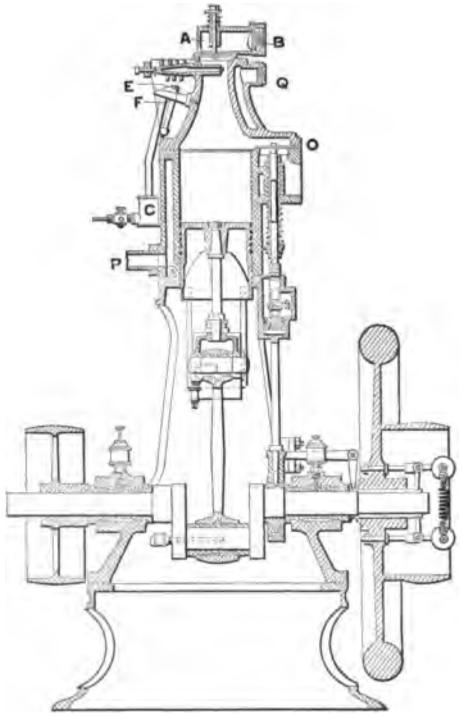


FIG. 55.—VERTICAL SECTION OF THE CAPITAINE ENGINE.

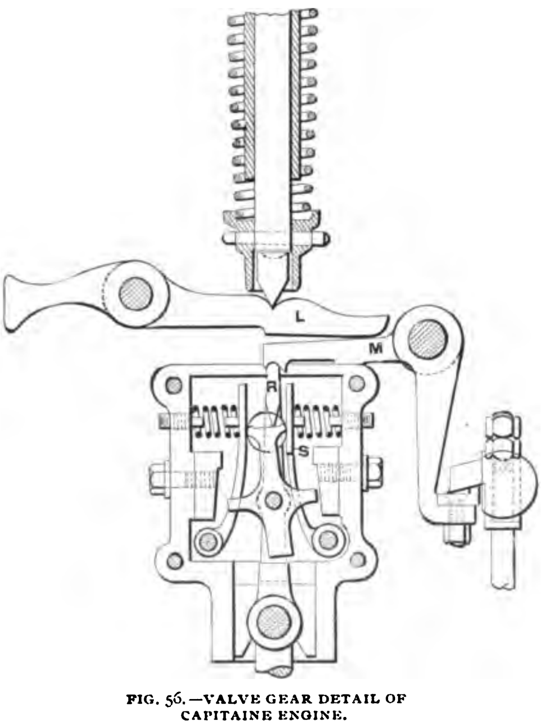


FIG. 56.—VALVE GEAR DETAIL OF CAPITAINE ENGINE.

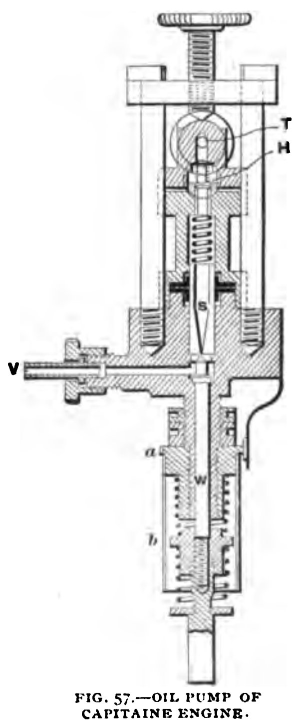


FIG. 57.—OIL PUMP OF CAPITAINE ENGINE.

the conical top point closes the bottom hole of the bucket S and carries the bucket before it, thus forcing the oil through the non-return valve H through T into the sprayer valve C of the vaporizer. On letting go the rod W, the non-return valve, the bucket, and rod will be pressed down by springs to their original position shown in Fig. 57. All parts of the pump can be easily got at after slacking the top screw and removing the traverse. The capacity of the pump is regulated by screwing up or down the nut *a*, thus limiting the stroke of the rod W, which is securely screwed to the nut *b*. When an engine of this kind is fitted to a launch, the pump is a suction and delivery pump of similar design, thus enabling the engine to pump oil from a tank below the pump. The vertical arm of the bell-crank ends in a detent which can be engaged by a corresponding detent N, Fig. 54, on a rod connected to the governor. The governor is carried in the fly-wheel, and transmits its motion through the boss to a sliding collar between the wheel and the bearing. A bell-crank and a rod connect the collar to the detent. The admission of oil is thus regulated by the governor according to the needs of the engine.

The operation of the engine is as follows: Explosion takes place with the piston on the top centre, after previous admission of oil-gas and air; the consequent impulse drives the piston down. On the upstroke the eccentric opens the exhaust valve and the burnt gases escape, the same movement of the eccentric also causing the feed pump to inject oil to the vaporizer. On the next downstroke there is admission or suction of oil-gas and air; on this downstroke and the next, the eccentric vibrating piece "misses," and on the upstroke the explosive charge is compressed, and when the piston is at top centre there is ignition and impulse. We thus have during two revolutions impulse, exhaust, admission of fresh charge, and compression. The exhaust pipe is connected to the chamber marked J in Fig. 54; Q and P in Fig. 55 are pipes leading from and to the water jacket surrounding the cylinder.

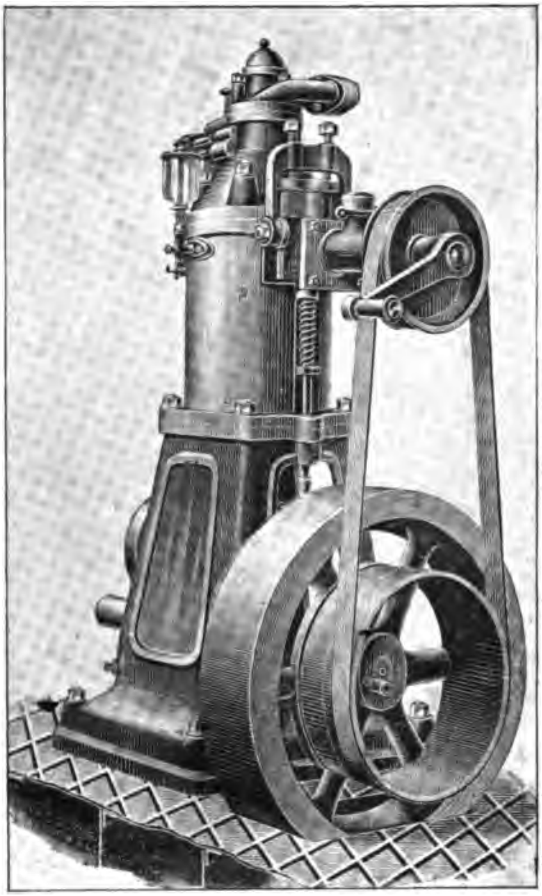


FIG. 58.—SINGLE-CYLINDER CAPITAINE LAUNCH ENGINE.

During the early part of last year a launch was on trial at Chester, England, fitted with one of the Capitaine engines, a friction gear being used for reversing or letting the engine run idly with the propeller shaft at rest.

The products of combustion from the cylinder were led to an exhaust chamber under a thwart, and from there were discharged under water. To the eccentric was attached a lever which worked a small pump. The latter circulated cooling water around the cylinder. An oil supply was carried in a tank in a bow chamber. The launch was thirty-five feet long by six feet ten inches beam by two feet six inches draught, and could comfortably carry about fifty passengers. The engine developed, as a maximum, six and one-half horse-power, and gave a speed of about eight and one-half knots an hour. The weight of the engine complete was about 2000 pounds. On the European continent launches propelled by these Capitaine motors are extensively used, especially at Hamburg, where a comparatively large number are at work.

The "Trusty" petroleum engine, built by Messrs. Weyman & Hitchcock, Limited, of Guildford, England, is shown in Fig. 59, the illustration representing a view of a double-cylinder engine, though the firm make also a single cylinder engine. Both types work on the four-stroke, or Otto cycle. In the double-cylinder engine, it will be noticed, the cranks are set together, and one impulse is thus obtained at every revolution, the cylinders acting alternately. Ordinary, refined oil of commerce is used in the engine. The whole outfit is made up of the engine proper, a small oil pump, and a vaporizer, the last being arranged at the end of the cylinder. The oil is poured into a small tank, which is separate from the engine and can be placed in any convenient position in the engine room.

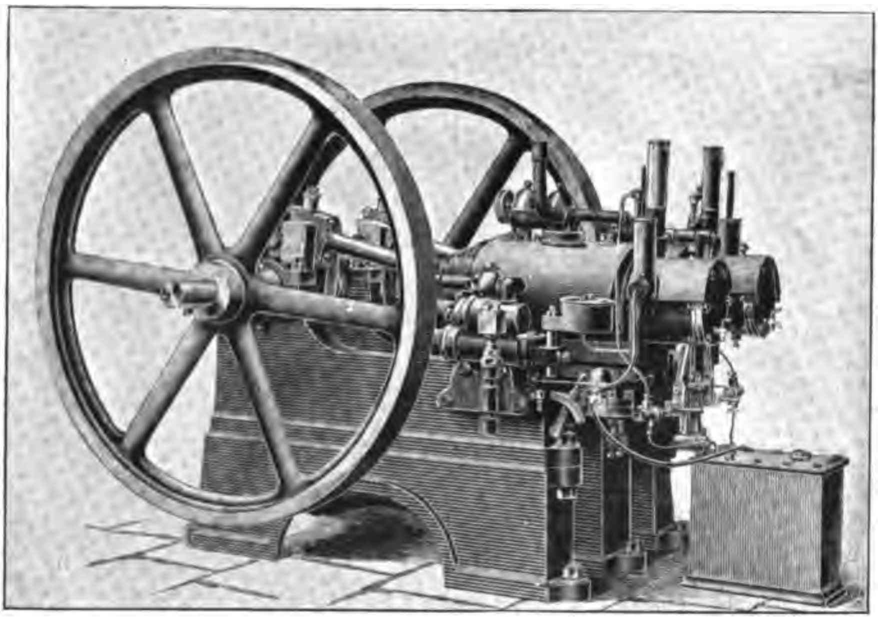


FIG. 59.—THE "TRUSTY" ENGINE, BUILT BY MESSRS. WEYMAN & HITCHCOCK, GUILDFORD, ENGLAND.

From this tank the oil passes to the pump through a small pipe, the pump being controlled by the governor. The requisite amount of oil is thus pumped into the vaporizer, and the vapor is drawn into the working cylinder during the suction stroke, mixing, in the cylinder, with a suitable proportion of air to make an explosive charge. Ignition of the charge is effected by an ordinary tube igniter kept hot by means of a small blow pipe flame.

The Brayton petroleum engine, shown in Fig. 60, has already been illustrated and described in a separate article in an earlier number of this magazine, but is here again incorporated for the sake of convenience and completeness. The illustrations, while showing one of the older types of Brayton engines, used with very good results in the United States, perfectly represent the principles of operation. The engine, as indicated by its name, belongs to the general class of petroleum engines, but in it no attempt is made to gasify or to vaporize, or even to heat the petroleum spray. The oil is finely divided—atomized in fact—in a large quantity of air, and is flashed into flame instantly. The combustion resembles that of flour dust or coal dust, suspended in the air, and which is so rapid that it constitutes an explosion. The combustible material is divided into infinitely small particles, and each particle is surrounded with an ample supply of oxygen, to which it exposes a surface which is very great in relation to its bulk. Under these conditions

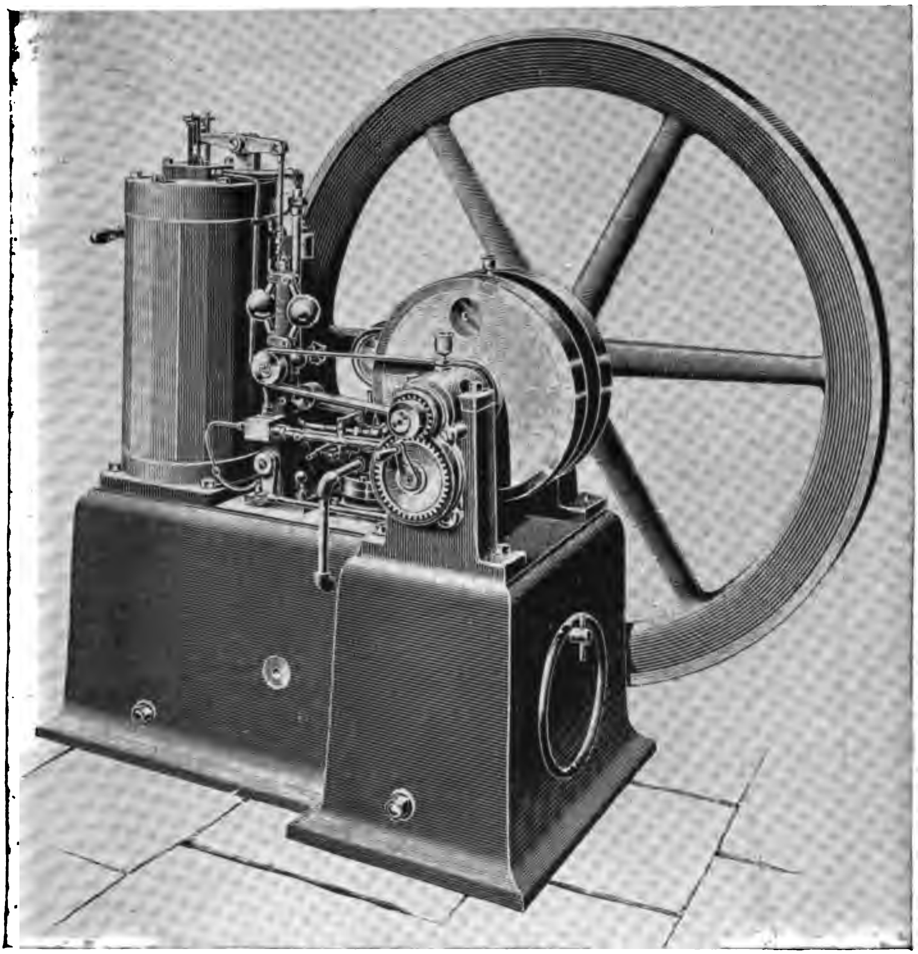


FIG. 60.—THE BRAYTON PETROLEUM ENGINE.

combustion is exceedingly rapid, and spreads from particle to particle with amazing celerity. The oil is burned suspended in air ; its combustion is complete, and is not impaired or delayed by metallic surfaces on which deposit can accumulate.

The method of ignition is entirely novel. As the oil is not admitted till the moment of explosion, there is no question of "timing" valves, or of attaining a certain degree of compression before the charge can be fired. A platinum is maintained at a glowing temperature within the cylinder.

The engine works on a modification of the Otto cycle. Explosion, exhaust, suction, and compression follow each other in the usual order, but the suction is a suction of air only (not gas and air), and the compression, also a compression of air only. Further, the exhaust valve is held open during the early part of the compression stroke to "scavenge" the products of combustion out of the clearance space, and to re-

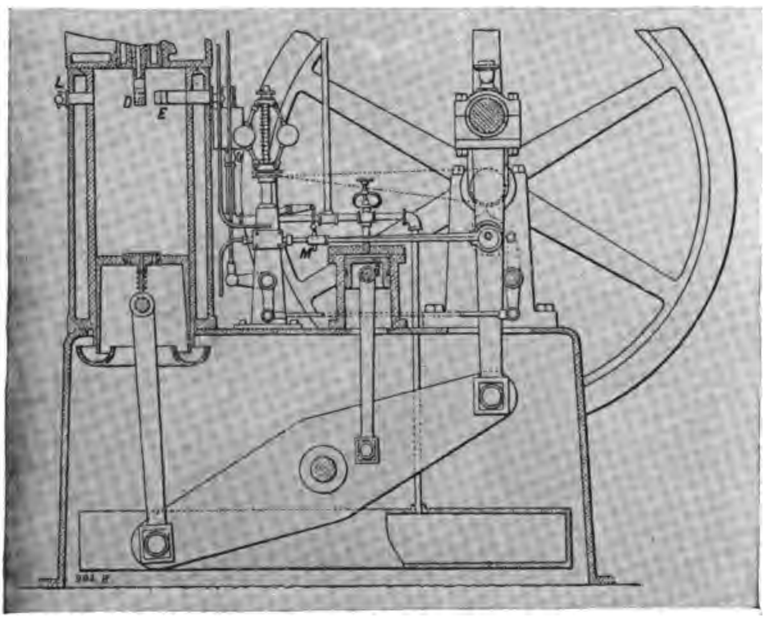


FIG. 61.—SECTIONAL VIEW OF BRAYTON ENGINE.

brilliantly incandescent surface can be maintained in the cylinder all the time, ready to ignite the first drop of oil that comes in contact with it. To do this, advantage is taken of the well-known phenomenon of flameless combustion, which is often shown on the lecture table, and but seldom found in practical work. A jet of air laden with hydrocarbon vapor is made to impinge continuously on a coil of platinum wire which has been previously heated, and as long as the jet is continued the place them by air. As the oil is sprayed into the compressed air in the cylinder it requires a blast of high-pressure air to effect its entrance. This air is obtained from a pump, which also supplies air to the incandescent burner, a pressure of eighty pounds to the square inch being employed for this purpose.

A sectional view of the engine is given in Fig. 61, while Fig. 62 shows some of the details. The general appearance of the engine is that of an inverted

beam engine, the beam being inclosed within the bed, and having a connecting rod at each end of it. From an intermediate point in the beam is worked the small pump which supplies the compressed air for spraying the charge and for maintaining the firing light. This pump is connected by a pipe to the cylinder head, shown on an enlarged scale in Fig. 62. The pipe A, together with the oil supply pipe B, to the sprayer D. The former consists of a tube in the end of which there are coils of platinum wire. These are separated from a packing of asbestos F by a perforated steel disc and a plate of wire gauze. A fine bore tube connects the firing device with the auxiliary oil reservoir G in which the oil is kept at a constant level by a float. Air from the pump is admitted to this reservoir by the pipe H ; part of it goes direct to

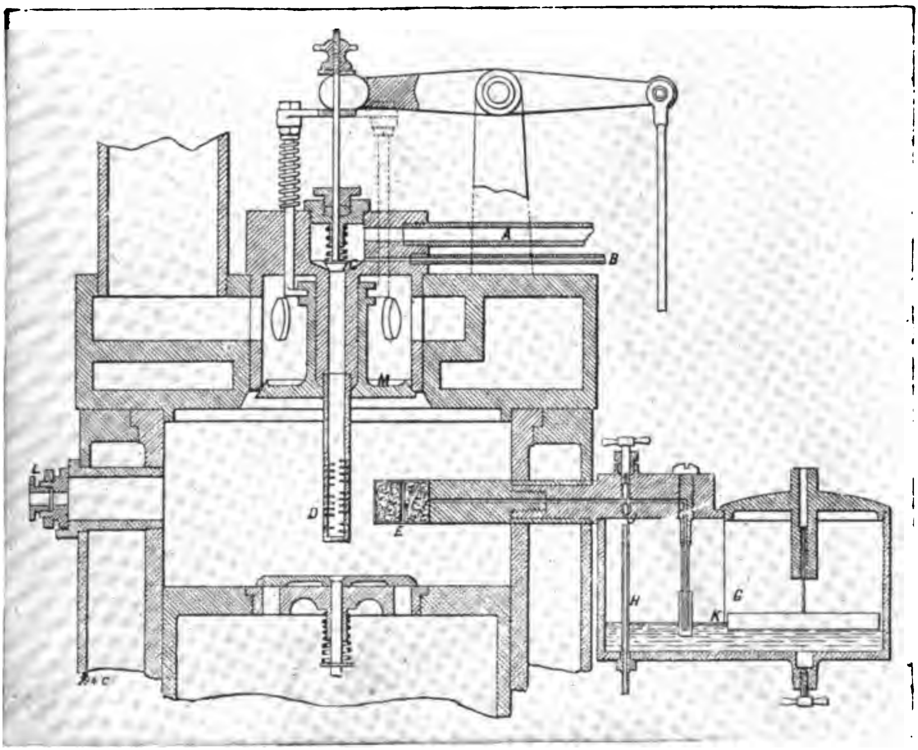


FIG. 62.—SECTIONAL VIEW OF BRAYTON ENGINE.

discharges into a chamber, the bottom of which is closed by a valve C. When this valve is lifted, the oil is driven violently down the pipe, and through the circumferential cuts at its lower end, into the clearance space of the cylinder. The oil is finely divided by the action of the blast and is driven out at several different levels in minute particles.

The igniting device E is placed near the platinum burner through the adjustable cock J and part through the device K. This latter consists of a perforated vessel having an internal pipe, the lip of which is below the oil level, so that oil and air are driven upon it in spray to the asbestos pad F. The heat of the cylinder continually vaporizes the petroleum in the asbestos, and insures it being carried forward in gaseous form to the platinum coils. In order to effect

the preliminary heating of the platinum, there is provided opposite to it a door L with a glass-covered aperture in its centre. This door is opened, and a torch is inserted by which the platinum is raised to a red heat.

The oil pump M, Fig. 61, is operated by an eccentric driven by one to two gearing from the crankshaft. The exact length of stroke of this pump is determined by a wedge, which occupies a position in a slot between the ends of the eccentric-rod and of the pump plunger. When the engine is running above the normal speed, the wedge is raised by the governor ; when it is running below the normal, the wedge is lowered and the stroke of the pump is nearly equal to that of the eccentric. A hand crank is provided, Fig. 60, by which the pump can be worked before the engine is started. On the same shaft with the eccentric is a cam for operating the oil inlet valve C, and the exhaust valve M, the former being opened when the left-hand end of the lever above it is raised, and the latter when it is depressed. The exhaust valve, as already stated, is opened at each revolution. It first evacuates the greater part of the products of combustion, and next it allows part of the air to blow through to scavenge the clearance space. This air is admitted by an automatic valve in the piston, Figs. 61 and 62, which opens as soon as a partial vacuum is formed in the cylinder. This position is chosen for the valve because the air can enter with little disturbance of the hot products of combustion, which congregate above, and can then sweep them completely out of the cylinder. To start the engine, the door L is opened and a torch of asbestos soaked in paraffin is introduced and placed beneath the burner E. When this is properly heated the torch is withdrawn and the door closed. A charge of oil is then injected by hand and the flywheel turned. On the compression stroke an explosion should occur, after which the engine runs without further attention. The cylinder is, of course, water-jacketed in the usual way.

(*To be continued.*)

THE FUTURE OF CAST STEEL.*

EVERY day we see a further development of the employment of the extra soft steel or homogeneous iron generally called cast steel. Without recounting all that has been said respecting the manufacture of this metal, it will be doubtless admitted that no metallurgical operation presents more precision or certainty than the working of the Martin furnace with basic or neutral hearth, or of the Thomas converter, which are the principal producing furnaces of cast steel.

In these days we no longer attach as much importance as in the past to the employment of very pure raw materials of well-known origin. Chemical analysis has taken the place of the foreman's eye in appreciating the purity and quality of the material used in working. What matters the quantity of phosphorus of the pig or scrap worked in the Martin furnace, since this phosphorus is sure to be eliminated in the course of working, thanks to a suitable addition of lime, which forms a basic slag capable of retaining the phosphoric acid proceeding from the oxidation of the phosphorus charged? We might say as much up to a certain point of the presence of sulphur. This substance, which very justly occupies the attention of manufacturers of soft steel, can now be very easily eliminated by a preliminary operation in the presence of manganese. The Martin furnace, with basic or neutral sole, is there-

* By permission of La Metallurgie.

fore a purifying apparatus in which the most impure materials may be placed in order to obtain cast steel of very good quality.

The basic converter permits also of the treatment of impure pig highly charged with phosphorus. A pig containing two per cent. of phosphorus can give in a few minutes a cast steel only containing some ten thousandths of this metalloid. Such an elimination would have appeared impossible before the year 1879 to the most daring metallurgists, brought up in the well-justified fear of this baneful element. This impossibility is solved now every day in the steel works of Cleveland, Westphalia, and the Est Department of France.

The Martin furnace and the converter have become docile instruments in the hands of manufacturers. Is this to say that nothing more remains to be done to improve their working? Certainly not. The re-carburation of this metal by the aid of specular manganesiferous pig presents difficulties which will some day be obviated by direct re-carburation on the Darby process by means of coke. Is it not, in fact, the simplest method to add carbon to a metallic bath? According to the statements of M. Thielen, the re-carburation by coke is practiced at the present time with success in his works. This is the latest very important improvement made in the manufacture of cast steel.

We must not lose sight of the fact that the manufacture of cast steel by the basic process gives rise to a calcareous slag more or less rich in phosphoric acid, according to the degree of impurity of the pig treated, which finds a very advantageous outlet in agriculture as manure and improvement of the soil.

In general, the slag proceeding from the basic converter in which very phosphorous pig is treated contains from 15 to 20 per cent. of phosphoric acid. The slag proceeding from the Martin furnace is ordinarily less highly charged with phosphoric acid, but, on the other hand, the phosphoric acid is more easily assimilated by the plants. This is doubtless because it has been formed at a sensibly lower temperature than the slag of the converter.

Still further practical men are daily improving the conditions of working. There results from this greater facility of execution, an appreciable diminution of waste, and, in consequence, a lowering of the cost of production. To such an extent is this the case, that in important adjudications cast steel is often offered at a price lower than that of wrought iron of average quality, and even of superior quality. This fact was brought out recently in Germany, in furnishing metal intended for the construction of a very important bridge.

A rapid glance at the chief properties of cast steel will show its superiority, as well in the course of the working of this metal cold as hot. It is the same with its electro-magnetic properties. When cold, the limit of elasticity and resistance to breaking are superior by about one-quarter to that of wrought iron. The lengthening is much greater, which permits of the metal being bent over and twisted without causing the least crack. The ductility of the metal is manifested in wire drawing and stamping. Tempering improves this metal by rendering it fibrous and more homogeneous. When hot, cast steel is characterized by extreme malleability, which is shown in the course of forging and rolling. The metal is easily welded, requiring for this no greater precaution than for very ordinary iron.

The Exposition of 1889 gave every one an opportunity of being convinced that cast steel may be described as weldable. This is a factor which it is desirable to insist on in a special manner, in order to dissipate all misrepresentations. Finally, the electrical conductibility of cast steel has been recognized in an official manner by the postal and telegraphic administrations, which have admitted this metal to participate in furnishing wire for telegraphic lines.

The uses to which cast steel is put are already numerous. We may cite

the manufacture of plates for boilers and thin sheets, black or tinned, known as tinned iron, or, more accurately, tinned steel. Wire works also absorb a large quantity of cast steel, which is specially suitable for this transformation. The weight of the ingots, the absence of flaws and seams, the regularity of scraping and drawing, are sufficient to justify wire manufacturers in their preference for cast steel. There are also rolled flat and corner pieces, and various other kinds of profile iron employed in building, which gain by being taken in ingots cast of steel. Wheel tyres, forgings, etc., also utilize cast steel advantageously.

Statistics show that every day cast steel tends more and more to replace wrought iron. In France, in 1887, the production of iron was 885,000 tons, and the production of steel was 269,000 tons, or 23 per cent. of the production. In 1889, the production of iron was 793,000 tons, and that of steel was 529,000 tons, or 40 per cent. of the total production of malleable ferrous products. The development made daily in the manufacture of cast steel enables us to affirm that before long—that is to say, at the expiration of a certain number of patents, whose termination is near—the figures which represent the respective production of iron and steel will be reversed, and the latter product will have definitely acquired the first rank, which is due to it, if we consider its exceptional properties. This result is already obtained in various metallurgical countries of Europe and America. The tonnage of cast steel annually produced far exceeds the production of wrought iron. It is thus that for the year 1887 there was produced in the whole world 8,720,000 tons of wrought iron and 9,850,000 tons of steel.

Cast steel is the metal of the present day. It will also certainly be the metal of the future. It will reign indisputably for some years, awaiting the advent of some other metal, aluminum perhaps, which will take the first place in the course of the next century.

G. A. Hirn

CASSIER'S MAGAZINE.

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FROM MINE TO FURNACE.

By John Birkinbine, Past-Pres. Am. Inst. M. E.

THE mining or quarrying of iron ores, coal and limestone, from the earth; their preparation, handling, transportation, and the smelting of the ores into pig iron, offer the theme for what could be made an instructive story, increasing in interest as we take into consideration the earlier history of coal and ore mining and iron production, and as we note the improvement made in processes, and the advances in quantity and quality produced. In several lectures delivered before the Franklin Institute of Philadelphia, in a presidential address before the American Institute of Mining Engineers, and in a contribution to the "Mineral Resources of the United States Calendar Year 1892," issued by the U. S. Geological Survey, the writer has treated several of these subjects in a necessarily somewhat disconnected manner. They are here brought together, however, in the shape of a comparatively complete and consecutive story.

The history of iron production and manufacture is old. We have been told of Tubal Cain in the seventh generation from Adam, being "an instructor of every artificer in iron," and of the use of this metal in the pyramids of Egypt, and in the gates of the city of Babylon, of the ancient book of Job mentioning "bars of iron," "barbed irons," etc. This iron was probably made in the simplest possible manner, the ore being taken from the ground, and converted into wrought iron, with the aid of wood or charcoal in heaps in pits, or in crude furnaces. But we need not go far back to trace developments, for the past half century, or even the last twenty years, show more advancement in this specialty than all the preceding years since iron was first mentioned as a metal.

To smelt iron ores a fuel and a flux are necessary, and in this country four fuels are employed, namely, anthracite coal, bituminous coal, coke made from bituminous coal, and charcoal. Coke is by far the most in demand for this purpose, and raw bituminous coal is used to but a limited extent, no record being now kept of the comparatively small portion of pig iron made with it exclusively. Including the output of furnaces using raw bituminous coal, alone, or mixed with coke, with those employing coke alone for this purpose we find that of all the pig iron produced in the United States, 70.6 per cent. is smelted with coke and bituminous coal.

Coke is also liberally used with anthracite coal in varied proportions in the eastern part of the United States,

DRIVING A CHAMBER

18.8 per cent. of the pig iron being made with these mixed fuels, and but 3.7 per cent. of our pig iron output being smelted with anthracite coal alone ; the remainder, 6.9 per cent., is produced by the use of charcoal. At present the relative employment of the different fuels ranks in the following order :

Coke, sometimes mixed with raw bituminous coal.

Anthracite and coke mixed.

Charcoal.

Anthracite alone.

Raw bituminous coal.

Limestone is the universal flux used, although different conditions require stone of varying composition, from nearly pure carbonate of lime to a mixture of the carbonates of lime and magnesia, known as dolomite.

Seventy years ago, the "burning stones" which we recognize as anthracite coal were first mined, but what has now become a magnificent industry grew with comparative slowness for two decades ; and it was not until 1842 that 1,000,000 tons of anthracite coal per annum were produced.

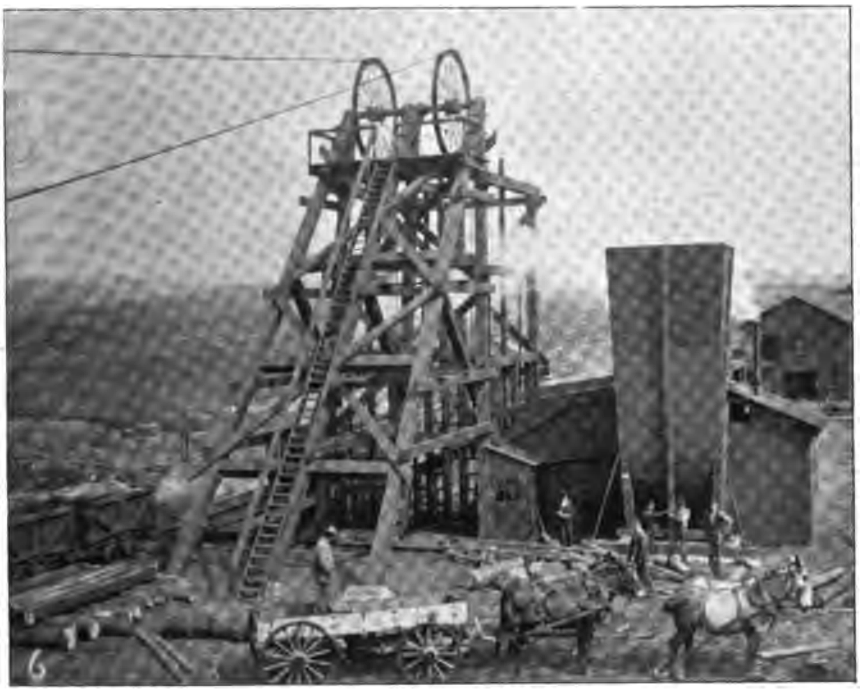
The opening of this fuel-field, however, soon exerted a stimulus upon railway and canal construction, some of the earlier enterprises and numerous later additions having been projected and maintained to carry anthracite coal to points of consumption or to navigable waters. And this stimulus reacted upon the industry itself. Larger shipments were demanded to meet the requirements of the market developed by these improvements.

From 1842 to 1864 the annual production of this form of fuel increased tenfold, from 1,000,000 to 10,000,000 tons, and this amount was again doubled (to 20,000,000 tons) in 1873. The shipments of anthracite coal for 1890 show another step in geometrical progression ; for, if to the 36,000,000 tons of anthracite shipped, we add the coal used at the mines, a production exceeding 40,000,000 tons is accounted for.

The astonishing record of the mining

industry within this limited area can be best appreciated by comparing the output with that of another mining industry. Thus, the weight of anthracite coal mined in Pennsylvania in 1892 was nearly three times as great as the total iron-ore product of the United States; and this coal was obtained at greater average depth, and under conditions generally less favorable, than are found at the iron-ore mines.

The total output of the anthracite regions of Pennsylvania for the past seventy years, approximates 750,000,000 tons. Of this, over twelve per cent. was obtained in the forty years between 1820 and 1860; fifteen per cent. in the decade following; nearly twenty-five per cent. between 1870 and 1880; and for the next ten years the output has averaged about 35,000,000 tons annually, aggregating nearly forty-eight per cent. of the whole. Of the total outptu of the_anthracite coal region as recorded, one-half has been mined since 1880. The production in 1892 exceeded 45,000,000 tons. Mr. J. H. Jones, special census agent, places the value at the mines of the anthracite coal product of Pennsylvania in 1889 at $65,721,578, demanding, at 362 regular establishments, the services of over 124,000 employees, who received in that year nearly $40,000,000 as wages. The capital invested in the coal lands amounted to almost $162,000,000; and this valuation does not include undeveloped properties nor any surface improvements except such as are necessary for mining and preparing the coal. If to the above amount were added the coal lands held in reserve, the numerous dwellings, and the enormous railroad facilities specially built and maintained to convey the product of the mines and breakers to trunk lines, the valuation would be greatly augmented.



AT THE MOUTH OF AN ANTHRACITE COAL MINE.

An approximate review of the con-

sumption of all kinds of fuel in the United States for the past twenty years may be obtained from the following census data :

	1870.	1880.	1890.
Gross tons of anthracite coal	13,925,229	25,580,189	40,714,721
Gross tons of bituminous coal	15,356,619	38,242,641	85,383,059
Bushels of charcoal	....	74,008,972	*90,000,000
Cords of wood	....	145,778,137	*180,000,000
Barrels of petroleum	5,260,745	26,286,123	34,820,306
Natural gas, value in coal displaced	No report.	No report.	*$20,000,000

The fuel consumption, per capita, in the United States, is in calorific value equivalent to three and one-half tons of coal per annum. Possible economies may reduce this to two and one-half tons for the same amount of work performed.

The fuel consumed in the United States, exclusive of natural gas, but including the coal and wood converted into gas, requires the conveyance, by various methods, of nearly one and a fifth million gross tons each day of the year (no unimportant factor in the national problem of transportation), and demands the energies of over one million wage-earners to mine, cut, handle, and convey it to points of consumption.

A MODERN ANTHRACITE COAL BREAKER.

By reason of the extended area of the bituminous coal fields, their development has greatly benefited the entire country. This fuel has supplied most of the illuminating and fuel gas, and, in addition to its liberal use for domestic and steam-producing purposes, the coke resulting from its distillation has influenced the iron industry to a won-

* Estimated.

THE CAGE WAITING FOR THE MORNING SHIFT.

derful extent, as is shown by the following figures, taken from the reports of the ninth, tenth and eleventh censuses: great quantities of wood, charcoal, oil, and natural gas. The United States is the great fuel consumer of the world.

Material Produced.	Gross Tons. 1870.	1880.	1890.
Pig iron	1,832,876	3,375,912	8,553,374
Manufactured iron	1,287,347	2,101,183	*2,518,193
Steel *a*, finished product; *b*, ingots	*a*44,426	*b*1,022,956	*b*3,988,327

The output of bituminous coal, added to the production of anthracite in 1892, brings the total of coal mined in the United States to eighty-three per cent. of that mined in Great Britain, the country which supplies nearly as much coal as all others in the world combined, exclusive of our own. In other words, the United States now produces over thirty per cent. of the world's output of coal, while it consumes, in addition,

* As the census statistics have not been issued, the above figures are taken from the report of the American Iron and Steel Association for 1890.

Over 2,000,000 cords of wood are annually cut to produce the 90,000,000 bushels of charcoal which I estimate were used in smelting ores of iron and of the precious metals, and for other specialties. The cord-wood used as fuel for various purposes largely exceeds that cut for charcoal, but the amount can only be roughly approximated. The total wood of all kinds used for fuel is estimated by Mr. B. E. Fernow, chief of the Forestry Division of the United States Department of

INTERIOR OF AN IRON MINE, SHOWING ROOF-SUPPORTING PILLARS.

Agriculture, at 180,000,000 cords per annum.

Peat is used to a moderate extent only; but various methods of drying or preparing it are passing through experimental stages.

In thirty-two years the product of petroleum has grown from 2000 barrels to 35,000,000 barrels annually, reaching a total for the whole period of 450,000,000 barrels. Of the present output, approximately forty per cent. is used for fuel; and this has a calorific value, three barrels of petroleum being taken as equivalent to one ton of coal, of over 4,500,000 tons of coal annually. The convenience of application favors the use of petroleum in localities where coal commands relatively high prices, and in cases where intermittent firing is employed; and we may anticipate a growing demand for this form of fuel.

It is perhaps impossible to determine the quantity of natural gas used in this country, but a measure of its importance may be found in the equivalent money value of coal it has displaced, which is calculated to approximate $20,000,000 annually. Moreover, the extensive introduction of natural gas for industrial and domestic uses has stimulated the employment of producer gas, and in many instances the manufactured gaseous has supplanted the natural solid fuel.

The magnitude of the quantities represented by our fuel supply emphasizes the importance of economies in its use. A saving of one per cent. of the fuel of all kinds consumed in the United States would be equivalent to 2,300,000 tons of coal per annum. If all the fuels produced in the United States were used for one year for the generation of steam, they would furnish continually, through boilers and engines of ordinary efficiency, nearly 12,000,000 horsepower; but if applied to boilers and engines of high economy, the resulting energy would be augmented to 25,000,000 or even 30,000,000 horsepower. An average reduction in American blast furnaces of one hundred weight of fuel per ton of pig iron made would amount to an annual saving of nearly a half million tons of coal, and proportionate economies in iron and steel manufacturing processes would more than double this saving.

The crowds of coal pickers covering a city's ash heaps attest the waste of fuel imperfectly consumed for domestic and manufacturing purposes, and the "smoke nuisance" (the abatement of

which is always in the future) is constantly before us as an indication of improvidence. The evil is to be overcome, if we believe the announcements of trade circulars, by patented boiler settings, which facilitate the evaporation of confided to the inventor only, utilize upward and downward draughts in the same chimney, the downward draught bringing the combustible myth to intensify immensely the heat of the normal fire. Economies are also claimed for

AN IRON MINE IN MISSOURI.

water at a rate in excess of theoretical perfection; by smoke consuming devices, which effect such economies that it will pay to burn coal merely to utilize the smoke; or by stoves or furnaces which, through some secret of nature special details in blast furnaces, heating furnaces, puddling furnaces, or other metallurgical constructions, some promising a return of more heat units than are accepted as theoretically attainable.

While many of the so-called fuel

A BATTERY OF COKE OVENS.

saving inventions are farcical, because they are based upon unsound theory, we are indebted to others for marked economies in fuel consumption, which have made it possible to advance metallurgy and manufactures to the position they now occupy. It requires but a brief retrospect to recognize the true economies.

Suppose for a moment that the quantity of pig iron and manufactured iron and steel now demanded by the United States had to be produced, manufactured, manipulated, and transported by methods in use two decades ago—how many tons of fuel would be wasted in producing the 9,157,000 tons of pig iron we made in 1892, if the blast furnaces were equipped with open fronts and fore hearths, following the custom of charging more fuel than the furnace could consume, so as to shovel it out at the bottom? What additional fuel would be required if gas producers were not connected with the furnaces in our mills and steel works, or if the direct methods of conveying molten metal from blast furnace to converter, and hot ingots or billets from converter to mill, or from one mill to another, were abandoned, and if our mills returned to the former practice of allowing the metal to cool between each two stages of treatment.

The developed coal mines of the United States could not possibly supply the present demands of the country if our industries, our locomotives, and steam vessels consumed fuel at the rate per ton of product or per horse-power that they did in 1873. Neither could the coal mines, as opened and equipped in 1873, produce the fuel now demanded.

Among the economies already achieved none are more notable than those adopted in and about the mines, by which the coal is removed with less loss in mining, and prepared so that, of that which formerly went to the dump piles, nearly all that is combustible is reclaimed. The application of finer sizes and even of the slack coal and dust to useful purposes is entitled to a prominent position among the fuel economies.

A critical review of the advances made in the methods and processes of mining, preparing, handling, and transporting coal, of producing and using steam, of smelting, refining, and manufacturing metals, would probably show that we are now able to accomplish with one ton of combustible mined, results which, twenty years ago, would have required the mining of two tons or more. If then he is entitled to credit as a benefactor who causes two blades of grass to grow where one grew before, we have cause for congratulation and for just praise that, in 1893, one ton of combustible taken from the mines benefits the country as much as, or possibly more than, two tons as removed, prepared, and used in 1873.

Such results, however, are not due to one man; to accomplish them, thousands of active minds have worked in one general direction, against difficulties and discouragements. The geologist, the mineralogist, and the explorer have done their part in locating and developing additional sources of fuel supply. The mining engineer, with the aid of the constructor and the mechanic, has brought to the surface, prepared, and delivered to consumers the solid, liquid, or gaseous fuels at low cost, while the laboratories of the chemists and physicists have contributed valuable data as to the composition and utilization of various fuels to assist the metallurgist and engineer in applying them.

The iron ores fed to blast furnaces, like the fuels just mentioned, are also of varying composition; the convenience of these to furnaces, the yield of iron, the proportion of other ingredients which they carry, such as silica, lime, alumina, magnesia, phosphorus, sulphur, titanium, manganese, etc., and the expense of mining the ores influencing their use.

CHARGING COKE OVENS.

A careful investigation of the consumption of iron ore and the production of pig iron in the United States, shows that the average yield of ore as charged into the blast furnaces of the country is about fifty-one per cent.; therefore, a little less than two tons of ore are required, on the average, to produce one ton of pig iron.

In 1892, as in 1890 and 1891, the United States led the world in the production of iron ores and in the manufacture of pig iron therefrom. Of these three years, 1892 showed the greatest

output of iron ore, viz., 16,296,666 long tons, against 16,036,043 long tons in 1890, and 14,591,178 tons in 1891, an increase of 260,623 tons over the product in 1890, and 1,705,488 tons more than that in 1891. In 1889, the iron ore product was 14,518,041 long tons, according to the eleventh census; the output of 1892, therefore, showed an increase of 1,778,625 long tons over the census year. If, as in previous years, an allowance of one and one-half per cent. is made for small or scattered mines not reporting, or of which no authoritative record is obtainable, the approximate total may be given as sixteen and a half million long tons of marketable iron ore mined in 1892.

The above statistics indicate that nearly equal amounts of iron ore were mined in 1889 and 1891, and one-quarter million tons more were won in 1892 than in 1890. The law of supply and demand often encourages a small annual output following a year of large production, or vice versa, and it would be equitable to consider the actual increase in iron ore output as represented more closely by the average of 1889 and 1890, 15,274,042 long tons, as compared with that of 1891 and 1892, 15,443,922 long tons.

It is well to remember that these large amounts represent iron ore ready for market, in winning which considerable quantities of lean ore, ochre, sand, rock, etc., are brought to the surface and there disposed of. Thus, most of the brown hematite iron ores must be washed to separate the earth, sand, ochre, etc., often one and one-half to three tons or more of material being required to yield one ton of salable ore. In the Lake Superior region large quantities of lean ore are taken out while mining the deposits of red hematite ; this lean material is used either as filling in other parts of the mines, or is stocked in piles to be cobbed afterward or used as ballast in road making. A considerable portion of this waste material contains a greater percentage of iron than some of the ores mined and smelted elsewhere, but it is not suf-

CONVEYING CULM FOR FILLING MINE CHAMBERS.

ficiently rich to stand the freight and handling charges from mines in the Lake Superior region to points of consumption, and there is at present insufficient local demand for the inferior ores. At Iron Mountain, Missouri, the lean red hematite is concentrated by hydraulicking and by jigging, and in the Marquette district of Michigan some of the ore is carefully hand-sorted. The leaner magnetites of New Jersey, New York, Pennsylvania, Michigan and North Carolina are enriched by magnetic concentration, or by jigging to a limited extent, or roasted to reduce sulphur; from one and one-half to five tons of material being treated to produce one ton of concentrated ore. The carbonate ores must be calcined for economic smelting, about two tons of ore resulting in one ton of "burnt ore."

In the year ending December 31, 1892, 163,444 tons of ore were obtained by magnetic separation, from 436,238 long tons of crude material; also 93,627 long tons of jigged ore were produced from 291,611 tons of crude material. This would show that on an average 2.67 tons of crude ore were required to produce a ton of magnetically separated ore, and 3.11 tons of lean ore to yield a ton of jigged ore. There were also 9555 tons of hand-sorted ore marketed as such. The amount of crude ore necessary to produce one ton of concentrate does not necessarily represent the relative merits of the two methods specified, the figures being introduced merely to show the practice in concentration during 1892.

In addition to the iron ore charged into the blast furnaces, considerable quantities of mill cinder, "blue billy," franklinite residuum, etc., are employed in the mixtures, and while it is impossible to obtain the exact amounts of all the materials used, it has been practical to collect the quantity of franklinite residuum so charged, which aggregated in 1892, 31,573 long tons, at an average value of $1.17 per long ton. On the other hand, considerable quantities of iron ores are used as "fix" or fettling in rolling mills, as a flux in silver smelting, etc., and it is equitable to consider that the amount of iron ore so employed is approximately offset by the quantity of other materials which are charged into the blast furnaces.

While the year 1892 shows an increase over 1890 in the amount of iron ore produced, the total make of pig iron in 1892 was smaller than in 1890. The ores won were not necessarily leaner in 1892 than in 1890, but the amounts of ore stocked at the mines in the Lake Superior region, and in other regions, were larger at the close than at the commencement of the year 1892. This was due partially to the fact that the production of pig iron in the last half of 1891 was much greater than in the first half, and this advance was but slightly checked in the first half of 1892, but in the latter part of last year the pig iron output was materially diminished, thus encouraging large shipments of ore in the first half of the year 1892, while the latter decreased demand led to stocking the ore.

There are to-day in the United States 650 blast furnaces, but many of these have been dropped from the official record by reason of having outlived their usefulness, or having failed to keep pace with the march of improvement, which raised our blast-furnace practice to a standard which commends the admiration of the world. This leaves a total of 564 blast furnaces on the active list.

Enthusiasts or novices still occasionally claim an ore yielding eighty to ninety per cent. of iron in spite of the fact that the magnetic oxide or protosesquioxide of iron (Fe_3O_4), the base of our magnetites, and the richest ore which can be obtained consists of 72.4 per cent. iron and 27.6 per cent. oxygen; and the sesquioxide of iron or ferric oxide (Fe_2O_3), the base of all our hematites, is a combination of seventy per cent. iron and thirty per cent. of oxygen. There is also the protoxide of iron or ferrous oxide (FeO), containing nearly seventy-eight per cent. of iron, but this does not exist in our ores except in combination, as in the carbonate of iron ($FeOCO_2$ or $FeCO_3$).

QUENCHING AND DRAWING COKE FROM OVENS

However, all the ores are mixed with earthy or rock gangue and carry sulphur, phosphorus, manganese, titanium and more or less water, and seldom approximate theoretical purity. The most notable instances of this approach are in large crystals of magnetite from near Port Henry, N. Y., and Republic, Mich., and in the harder specular ores of Michigan and Minnesota.

The iron ores produced in the United States may be divided into four general classes, without particular reference to their geological occurrence, but approaching within narrow limits the practice generally followed in the sale and purchase of iron ores.

(1) Red Hematite, all the anhydrous oxides of iron known by various names, such as red hematite, blue hematite, specular, micaceous, fossil, slate iron, martite, flax-seed ore, etc.

(2) Brown Hematite, including the varieties of hydrated sesquioxide of iron, variously known as limonite, gœthite, turgite, bog ore, pipe ore, pond ore, grape ore, and also some manganiferous iron ore, and most of the iron ores mined in the Rocky mountain region for the smelting of argentiferous ores.

(3) Magnetite, those ores in which the iron is found chiefly as magnetic oxide: this class also includes some martite mined with the magnetite.

(4) Carbonates, those ores which contain a considerable amount of carbonic acid, such as spathic ore, siderite, black band, clay ironstone, etc.

Notwithstanding the high proportion of iron in magnetic oxide, the red hematites mined in this country are, as a class, the richest ores in iron which we produce. This is largely due to the dissemination of crystals of magnetic ore through the gangue, or their mixture with other crystals, requiring in many cases the reduction of the ore to small size, and the separation by gravitation or by magnetism of the particles.

The red hematites differ only from the brown hematites in the former carrying less water than the latter, and the subdivision of the brown hematites into "turgite," "gœthite," "limonite" and "bog ore," etc., is mainly due to the water they contain, and the more or less intimate mixture of the peroxide and earthy matter. Of the red hematites the "specular," "micaceous," "dye stone" and "fossil" ores are determined by physical structure or association with gangue.

(*To be continued.*)

RECENT DEVELOPMENTS IN POWER TRANSMISSION.

By C. J. H. Woodbury, Vice-President Boston Manufacturers' Mutual Fire Insurance Company.

THE writer, at a meeting of the New England Cotton Manufacturers' Association last year, read a paper on the electrical transmission of power for cotton mills, and the board of management of this association, recognizing the importance which this method of power transmission is likely to assume, thought it desirable to continue the consideration of the subject.

At the last meeting of the society, at their invitation, I presented the following facts, and instead of confining myself entirely to practical results, I gave a little attention to some of the main principles involved, which will soon be as necessary a part of the knowledge of every manufacturer as the principles involved in water-wheels and steam engines are at the present time.

In the ordinary dynamo for electric lighting, each of the various coils of wire making up a section of the armature is brought into the circuit as its commutator bar comes in contact with the brush, and in that manner contributes to the circuit for electric lighting or power the current of electricity which it has produced by being pulled across the attraction of the magnets of the dynamo.

In the reverse manner, if electricity were applied to such a dynamo, it would energize the magnets, pass through the wires of the armature, and the attraction of the magnets would cause this armature to revolve and convert the dynamo into a motor, because the magnet attracts each coil of the armature, and as it moves around to proximity to the poles of the magnet, the electricity is switched out of such coils by the commutator, and the magnets exert no further attraction upon coil, but is ready to exercise a similar attraction for the next section, for it must be remembered that the attraction which the magnet exerts is not upon the wires of the armature, for they are made of copper, but upon the current of electricity conveyed by these wires. A current of electricity is subject to magnetic attraction similar to iron, as may be seen by applying a magnet to a lighted incandescent lamp. The carbon filament is readily bent as if it were a very fine iron wire, but if the lamp is not lighted, the carbon filament is not affected by the magnet.

The question naturally arises, why should not iron or steel wires be used in the armature? The one sufficient reason is that the magnets would attract a section of wire in the armature and would hold it stationary. Whereas, when the attraction is exerted upon a current of electricity in the coil of wire in the armature, that principle can be used to produce a motion by the ready manner in which the electricity can be conducted through or removed from any coil of iron in the armature to meet the mechanical necessities of the case to produce a rotation of this armature.

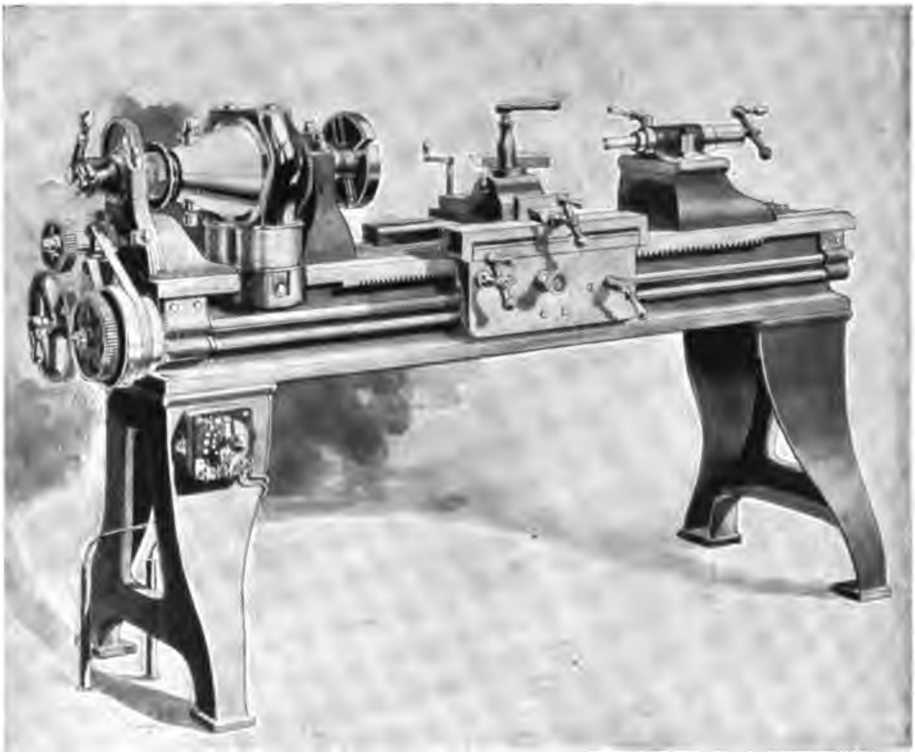
I have gone into this matter at some length in order to state the principle of the ordinary continuous current motors, which is that the magnet remains stationary, and that the electrical currents are moved from one set of wires to another in the armature as occasion requires.

In the dynamo the electricity is generated in the armature in currents passing to and fro, first in one direction

and then in the other, forming what is known as the alternating current. The function of the commutator and the brushes upon a dynamo is merely to convert this alternating current into a continuous current. There is no reason why an alternating current is not just as well suited for electric lighting as a continuous current.

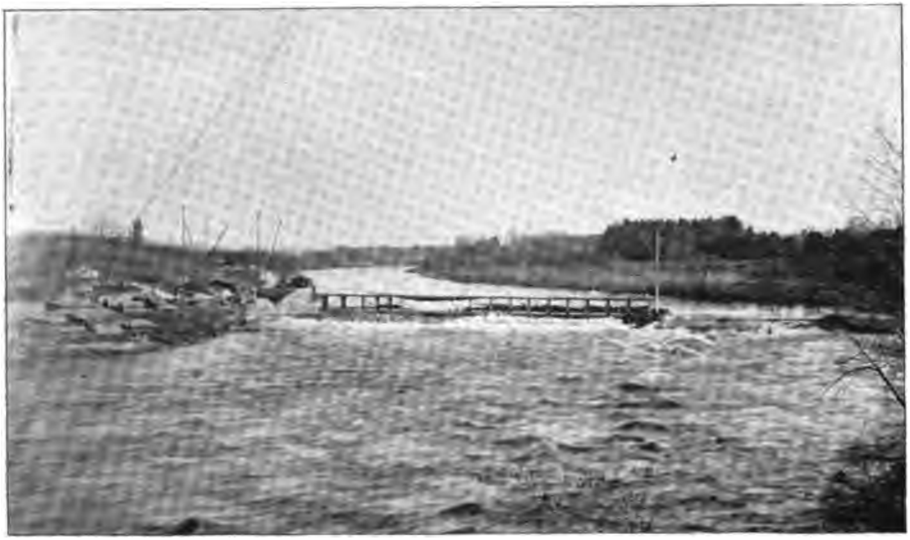
But many years ago, when Sir Frederick Siemens, one of the pioneers in the application of electricity, made a dynamo for arc lighting, he required a continuous current to operate the regulator in the upper part of his arc lamps, and instead of trying to invent a form of regulator to feed the carbons, which could be operated by an alternating current, he placed the commutator and brushes on the dynamo, producing a continuous current, and in that manner set for years the practice of electric lighting by continuous currents, although in the meantime there have been numerous devices for regulating the carbon feeding mechanism of arc lamps by alternating currents.

Electricians have of late years begun at the place from which they were diverted a number of years ago to investigate and apply alternating currents for lighting and power purposes. These investigations have opened up a wealth of electrical principles and applications of which the world has but just seen the beginning.



LATHE DRIVEN BY CROCKER-WHEELER ELECTRIC MOTOR IN HEAD STOCK.

One of these new forms of alternating currents is what is called the multiphase current, of which the electricity is generated in waves; one wave following another before the first wave has been completed, using currents of electricity which will affect other apparatus by induction through space and without the



SEWALL'S FALLS IN THE MERRIMAC RIVER, NEAR CONCORD, N. H.

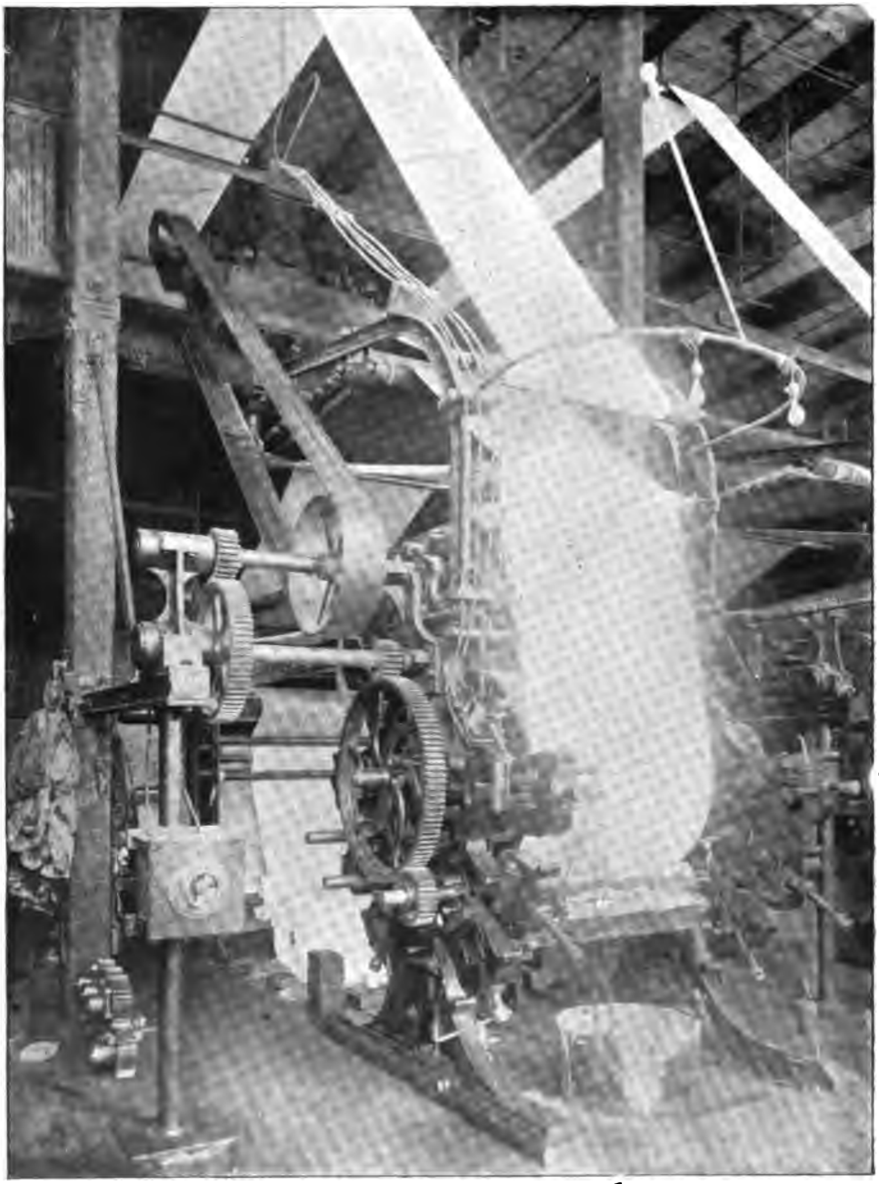
intervention of metallic conductors, being, as a matter of principle, comparable to the results produced upon a telephone system when it receives by induction the noise of electric motors or the click of the message transmitted along telegraph wires in juxtaposition to the telephone wires, or even the voice which is transmitted over other telephone wires.

In its application to these multiphase motors I would say that the method of construction differs entirely from the motors hitherto in use. Instead of using commutator and brushes to transfer electricity from one part of the armature to the other, as has been already alluded to in the continuous current motors, the magnetism revolves, through the magnet, causing the armature to revolve in exact synchronism with it.

For purposes of comparison the general arrangement of these motors may be compared to that of a hat rim, as representing the circular magnet, and a ball of twine stands for the armature of the inside, which is a suitably wound collection of insulated wires joined together at the ends and not electrically connected to anything else. Electric wires from the generators are wound upon this circular magnet, and the wave-like currents which the wires carry produce similar magnetization traveling around and around through the magnet, and by this inductive effect to which I made allusion, electric currents are produced in the wires of the armature, so that it will be susceptible to the attraction of the magnet. The wires in the armature revolve, following the attraction of the magnetism circulating in the magnet.

Dynamos similar in principle produce the waves of current which supply this motor, but for economy in transmission, both as regards the small amount of wire and the small loss by resistance, these currents can be generated at a high electrical pressure, which is increased by transformers for the main wires, and then at the motors reduced to a very low pressure by transformers, which answer the same purpose as the reducing valve for steam, except that they can act in either direction to increase or reduce the electrical pressure.

The other advantage of these multiphase motors are that being without any brushes or commutators, there is no sparking. There is hardly a possi-



ELECTRIC MOTOR OPERATING CALICO PRINTING MACHINE AT THE DUNNELL PRINT WORKS PAWTUCKET, R. I.

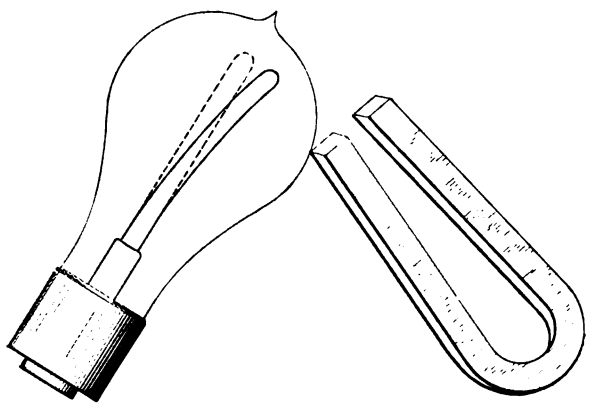
bility of a burned armature. The motor being operated by a succession of wave currents will keep at a speed comparable to that of the generator as long as it can keep up. If overloaded, it will not run slower, but will stop. Under similar conditions of overloading, a continuous current motor will burn its armatures unless defended by its safety fuses. Its regulation is very close ; the variability of some tests being only one and one-half per cent. between no load and its full load. Such a motor will start under its full load or even greater.

In connection with such a system of electrical transmission of power it is feasible to use a portion of the current for incandescent lighting without any interference. These motors can be stopped and started without the exercise of any particular skill, and can be enclosed for protection against dust and dirt in a case which merely allows for the protrusion of the shafting carrying the driving pulley.

These types of motors, although new, have received thorough application and exhaustive tests in the works of the electric companies engaged in their manufacture. It is, however, scarcely time for their use in commercial lines in this country, but they will be very fully exhibited at Chicago.

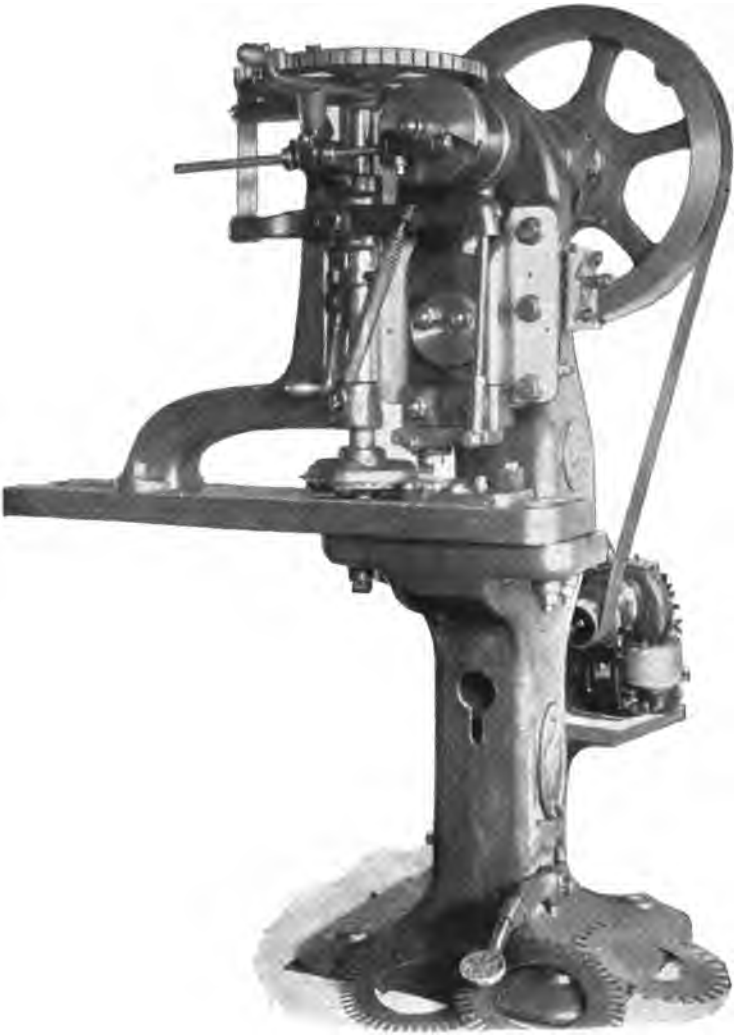
It is this type of electrical apparatus which will be used in transmitting the power from Sewall's Falls on the Merrimac river, about four miles north of Concord, for power and lighting throughout the city of Concord, and also to any establishments which may be built on the large tract of land in the vicinity owned by that company. There is a capacity of 5000 horse-power at this point, and it is expected that 3500 horse-power will be distributed during the early summer.

The uses of electric motors in connection with the transmission of power are becoming more widely extended, one of the best examples in this vicinity being that of the Page Belting Company at Concord, N. H., where the power is distributed throughout their extensive new establishment by means of electric



INCANDESCENT LAMP FILAMENT DEFLECTED BY MAGNET.

motors, for which the electricity is generated in the original works of this company. George F. Page, the president, informs me that the whole cost of the electrical apparatus was twenty per cent. less than would have been required for a steam plant applied in the usual manner. There is a further economy by reason of the elimination of much of the shafting required in connection with the transmission of power from numerous motors in comparison with the shafting and pulleys which would have been required to distribute the power from a steam engine on the premises. The largest shafting now in these works is two and one-half inches in diameter; but if an engine



PUNCH PRESS DRIVEN BY ELECTRIC MOTOR.

had been used the main shafting would necessarily have been at least five inches in diameter, and the length of shafting many times greater than at present, the difference in this respect being greater than in cotton manufacturing, on account of the greater distance between the various machines.

In addition to safety and convenience it may be interesting to note that this method of transmission has been carried out in such a way that there is not a single open hole through the floor for any purpose, the openings for the steam pipes being packed around with asbestos. This transmission of the power from the old works is only temporary, as it is proposed to connect with the electrical power derived from the water-wheels at Sewall's Falls as soon as that installation is completed.

I have been informed that at a new cotton mill in South Carolina the power will be transmitted by wire to a motor driving the line shafting in each room.

One of the latest applications of the

electrical transmission of power is in the Crocker-Wheeler Electric Works at Ampere, N. J., where a pair of copper rods answer as line shafting, and from them the connections are made at will to motors operating machine tools in various parts of the establishment. In some instances it has been preferable to drive short lines of shafting by motors and to belt down in the usual way. In the former case, the motor is attached directly to the machine, as for example, under the headstock of a lathe, and in place of using the cone pulleys for variation in speed, or the clutch for reversing the direction of the motion, the lathe is controlled by the operator in a manner comparable to the usual way in which the motorneer of a street car controls the speed or direction of the car ; and from these same wires at every machine an incandescent lamp, suitably protected by wire guards, is used whenever artificial light is necessary, and such light can be placed on the carriage, or wherever it may be desirable to apply the light for the purpose of the work in hand.

The operation of a calico printing machine probably presents the greatest difficulties in the application of power of any machinery in textile manufacture. The machine must be driven at will with variable speed, and any shock in the gradations from one speed to another may impair either the machine or the product. The cloth must be moved at times to a slight extent in either direction, and the whole must be absolutely under the control of the operator. As an absolute statement these requirements are almost an ideality. Up to the present time a double cylinder steam engine to each machine has furnished the best method of driving, notwithstanding that the heat and the floor area occupied by the steam engine is necessarily an interferencce in the printing room. When the printing machine stops, the rolls sink into the blanket, and it requires an excess of power to start it, as if it were a heavily-loaded team on a soft road.

A recent application of electric motors has given practical results of the greatest importance in operating printing machines at the Dunnell Print Works in Pawtucket. At the time of their reconstruction after their late fire about two years ago, W. W. Dunnell, wishing that the new print works should contain all of the improvements possible in the business, considered favorably the suggestion that electric motors should be tried for the operation of printing machines. A motor was applied to a seven-roll printing machine in order to give the matter a thorough trial.

This work was undertaken in spite of the skepticism of his associates and the opposition of the men engaged in the printing room. There were some difficulties at first, primarily owing to the fact that the electricians were not calico printers, as well as that the printers were not electricians. It required a little time for each to learn of the other; but since the several modifications in the arrangement for this work were introduced, the operation of the system has been not merely satisfactory, but has given results in advance of any other method of driving a printing machine.

In the electric lighting station of the works an Edison lighting dynamo with a separate exciter is used for generating a current to drive a motor which was placed on the unused portion, next to the rail, of the mezzanine floor, or what is known in the printing room as the platform. For speed and direction it is controlled by a hand wheel and switch at the front of the printing machine.

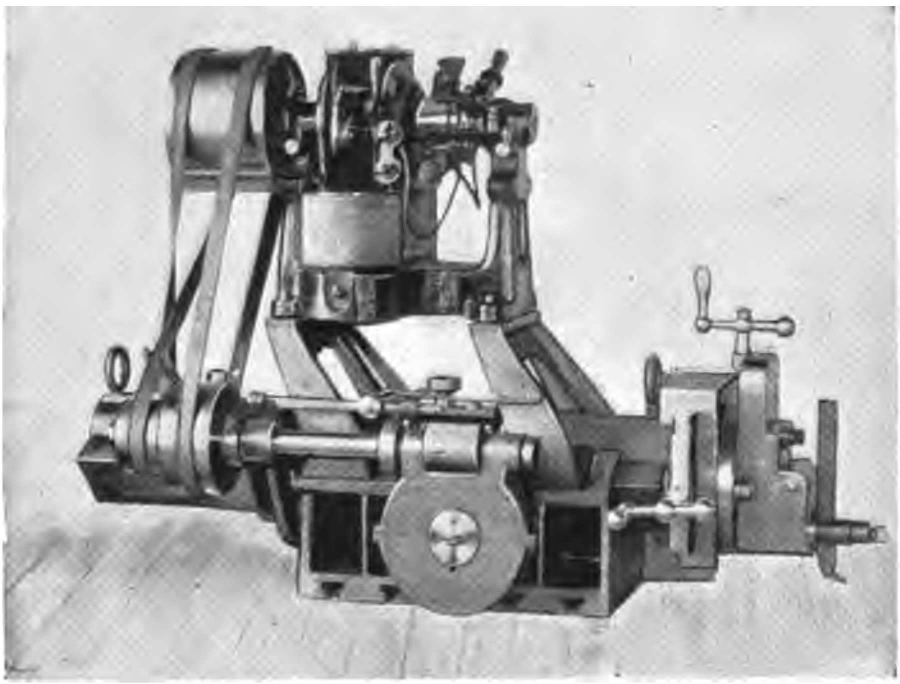
This device has had a practical trial of eighteen months' duration with the most satisfactory results. By its uniformity in rotation the cloth is printed at fifty per cent. greater speed than with the steam engines in the same room. The driving is under absolute control. The cloth can be moved at will for a short distance, as an inch, if necessary. There is an absolute gradation of speed from one velocity to another, and that without any shock. These changes are so uniform that the doctor never cuts into the copper roll.

The speed can be kept uniform at any desired velocity, and the machine can be stopped and started by anybody working at it. In its operation it does not require the exercise of any technical skill.

I have alluded to the maximum speed as fifty per cent. greater than with the steam engine. The uniformity of its motion can be seen by any one watching the machine, particularly in the absence of the chattering of the gears. All printing machines are necessarily still for changing of rolls and other purposes a portion of the time, but the whole production of this machine is more than thirty-three and one-third per cent. greater than that of the machines driven by steam. When it is considered that a print works plant is worth more than $50,000 per machine, the value of a device which will increase the output one-third is sufficient to introduce radical changes in this line of manufacturing.

Mr. Dunnell stated to me that his experience, as shown by this trial, has revealed such facts in regard to the capacity and capability of the electrical transmission of power for print works, that if one were to begin anew the construction of such works, he should advise, instead of the numerous steam engines about the premises, the generation of all the power at a central source, and its transmission throughout the establishment by electricity.

This use of motors for the operation of printing machines is the first practical instance of its kind, and its adoption and persistent and faithful trial confirms the enterprise of Mr. Dunnell, and also reflects great credit upon the practical skill of Sidney B. Paine, the manager of the mill power department of the General Electric Company, notwithstanding that his modesty prompts him to disclaim the whole solution of the problem in which he was the moving spirit, and ask for due credit for his



ELECTRICALLY DRIVEN PORTABLE SHAPER.

able coadjutors. The whole tendency of later invention in regard to electric motors appears to be in the successful use of large motors.

The Baltimore and Ohio Railroad are to use three 120-ton electric locomotives for carrying the trains in the tunnels under the city of Baltimore, being able in that manner to perform the same service in traction as with the largest locomotives and without producing any smoke to interfere with the air in the tunnel. In connection with these locomotives is a supplementary motor, which produces an air pressure for the air brakes and also for the whistle.

The advantages of electrical transmission of power is largely those of the relation of the position of the machinery with the motive power of the establishment. Each room is entirely independent from other rooms, and any motor is always ready for service as long as the machinery from which it derives its electricity is in operation.

HEATING FEED WATER BY LIVE STEAM.

EDITOR OF CASSIER'S MAGAZINE:

I HAVE been much interested by the article in your April issue on heating boiler feed water, in the latter part of which the author mentions a method in which the steam used in heating the water is taken from the receiver of a compound engine. I think, however, that it is a mistake to compare this method with the system of live steam heating, as there is, to my mind, not the slightest similarity between them. The results of the first named method are perfectly obvious, whereas in the latter the results claimed are due to causes at present unexplainable.

I have for some time had in operation the system in which steam to heat the feed water is obtained from the receiver of a compound engine, and it may be of interest to your readers to know of the results obtained and of the apparatus used. To fully understand the reasons for the economy obtained by the use of this method, it will be well to investigate a particular case from a theoretical standpoint. Suppose the system to be applied to a 500 horse-power engine using fifteen pounds of water per horse-power, the engine being supplied with steam from boilers that are evaporating nine pounds of water per pound of coal from a temperature of 100 degrees (about the average temperature of water from the hot well). If the boiler feed water is raised from 100 to 200 degrees by steam taken from the receiver of the engine, the steam required will be about ten per cent. of the total amount passing through the receiver. Assuming that each side of the engine is doing one-half of the total work, or 250 horse-power, under normal conditions if ten per cent. of the steam in the receiver be abstracted, the power of the low-pressure cylinder will be reduced proportionally, which in this case will be twenty-five horse-power. This loss of power must evidently be supplied by the admission of more steam to the high-pressure cylinder, which under the above conditions will be 375 pounds. By the heating of the feed water 100 degrees, a gross saving of ten per cent. of fuel is made, but the extra steam used to compensate for the loss of power occasioned by the use of steam from the receiver will cause a consumption of five per cent. more fuel. There is, therefore, a net saving of five per cent. The above figures are simply approximately correct. The theoretical results and those in practice will be found to differ slightly. In practice the economy obtained will be found somewhat less than the theoretical, and I think the discrepancy is due to the disarrangement of the steam

distribution in the cylinders. The apparatus employed to accomplish the desired result was as follows : A Warren Webster exhaust steam economizer was employed as the heater, because in this type of heater all steam entering it is condensed, and all waste from leakage prevented. It is also entirely closed to the atmosphere, and, therefore, it is possible to carry a slight vacuum in the body of the heater. A four-inch pipe connection was made between the heater and receiver, and in this pipe a pressure reducing valve and an oil extractor were placed. The reducing valve is used to deliver the steam to the heater at atmospheric pressure, and to stop the admission of steam when the water is either not being withdrawn or is sufficiently heated. The oil extractor is made necessary from the fact of the heater being of the open type. It was found by experiment that the reducing valve could be set so that the temperature of the water could be maintained at 200 degrees. Exhaustive tests were made to determine the efficiency of this method, and the average results obtained showed a net saving of four and one-half per cent. The engine to which the heater was attached is a Corliss cross compound, 24 x 46 x 60, running sixty-two revolutions per minute, and at the time of the tests was developing 500 horse-power. The receiver pressure was reduced about one and one-half pounds by the withdrawal of the steam. SAMUEL M. GREEN.

HOLYOKE, MASS., June 1, 1893.

MODERN GAS AND OIL ENGINES.

By Albert Spies, Mem. Am. Soc. M. E.

Fifth Paper.

A FIELD which almost from the beginning of the oil engine industry had suggested itself as a promising one for the extensive use of engines of that class is that of agricultural engineering. Steam engines have for quite a number of years been largely employed in agriculture, and have demonstrated conclusively that something more than man power has become necessary to economically carry on much of the farm work of the present day. For such work, however, steam engines have always carried with them the dangers of steam boilers, necessarily entrusted to the care of comparatively unskilled attendants, and it has become generally recognized that if some other, less dangerous source of power were available, it would be well worth having. Oil engines with their comparative simplicity and absence of complication in management appeared to exactly meet the requirements, and as a consequence portable outfits were built and are already much used for threshing and other similar purposes.

One of the makes which has become prominent in this line is the Hornsby-Akroyd oil engine, of which a portable form is shown in Fig. 64, while Fig. 63 represents the stationary design. It is built by Messrs. Richard Hornsby & Sons, Limited, of Grantham, England. The engine is horizontal and works on the well-known Otto cycle. It is constructed with a working cylinder closed at one end by a cover and open at the other. In this cylinder works the piston, which is formed like a plunger, being open at one end to receive the end of the connecting rod. Near the closed end of the cylinder a valve box is fitted, which contains two valves, one being the air valve and the other the exhaust valve. The air and the exhaust valves are operated by separate levers, each lever being moved by a cam mounted on a horizontal shaft, driven by the crankshaft through skew or bevel wheels. This horizontal shaft makes only one revolution while the crankshaft makes two, so that the air and exhaust valves are each opened only once in every two revolutions.

At the back of the cylinder is a cast-iron box, called the vaporizer, which is always open to the cylinder through a neck. This vaporizer is heated, before starting the engine, by an external lamp blown by a small fan for a few minutes, so that the vaporizer shall be able to vaporize and explode the oil when it is pumped into it. After the engine has started running, the lamp is no longer required, the vaporizer being kept hot enough by the explosions which take place in it.

A small oil pump worked by the air valve lever draws oil from the oil tank under the engine and forces it into the vaporizer ; this takes place only during the outstroke of the piston, when it is drawing in air. The oil on its way from the pump to the vaporizer passes through a valve box attached to the vaporizer. This valve box has two valves in it, one kept closed by a spring which the oil forces open as it goes into

the vaporizer. The other is also kept closed by a spring, and should the engine run too quickly, the governor opens it and allows some of the oil to flow back to the tank. This valve can also be opened by turning a little regulating handle, which will stop the supply of oil to the vaporizer, and thus stop the engine. The action of the engine may be explained as follows :

The vaporizer having been previously heated and the fly-wheel being pulled round, the first outstroke of the engine thus made will cause air to be drawn into the cylinder, and at the same time the pump will force oil into the vaporizer, which is immediately transformed into oil vapor. On the return stroke of the piston, the air is compressed into the vaporizer and thereby mixed with the oil vapor, and just as the piston gets to the end of its stroke, and the compression is, therefore, greatest, an explosion takes place, which forces the piston out on its second stroke. When the piston gets to the end of this stroke the exhaust valve opens, and the return stroke expels the gases, the same cycle of operations being repeated continuously.

The speed of the engine is governed by a small Porter governor which acts through levers on an overflow valve fitted in the valve box attached to the vaporizer, so that when the engine runs too quickly this valve is opened by the governor and the oil allowed to return to the tank instead of going into the vaporizer. The latter getting little or no oil, the speed of the engine is thus regulated.

The oil used for running these engines can be varied from oil of a specific gravity of .8 to one of .85 and even .88, with flashing points of from 200 to 250 degrees Fahrenheit.

The outline drawing, Fig. 65, will help to further explain the general construction and manner of working of the engine. In this, P represents the exhaust valve lever ; Q is the oil pump, and R is the small fan referred to, driven from the pulleys S. The vaporizer lamp is shown at T, the vaporizer itself being marked V ; H is the cam shaft, and K are the governor gear wheels ; B is a cylinder oiler ; M is the connecting rod from the governor to the vaporizer valve box X. The water circulating pipes for the cylinder jacket are marked *a* and *b*, and those for the vaporizer valve box are marked *c* and *d*. The oil supply pipe *f* from the tank to the pump has a three-way cock *e* with a fitter inside ; *g* is the oil pipe from the pump to the vaporizer valve box, and *h* is the overflow pipe from the vaporizer valve box to the oil tank.

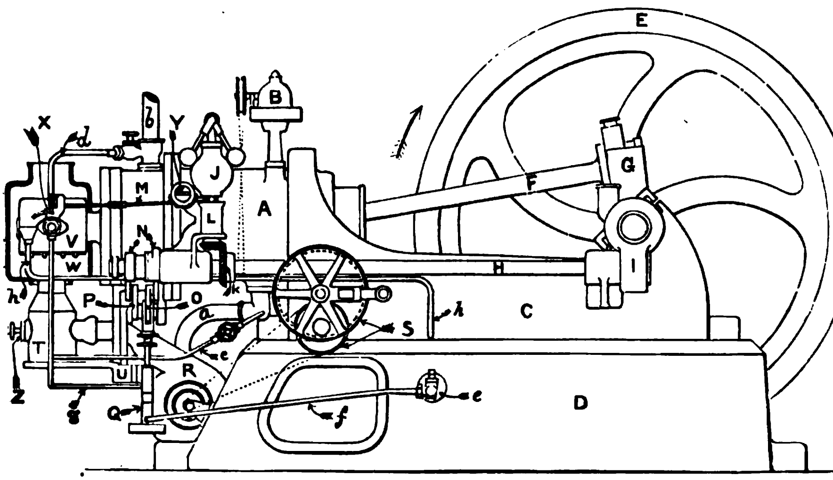


FIG. 65.—EXPLANATORY DIAGRAM OF HORNSBY-AKROYD ENGINE.

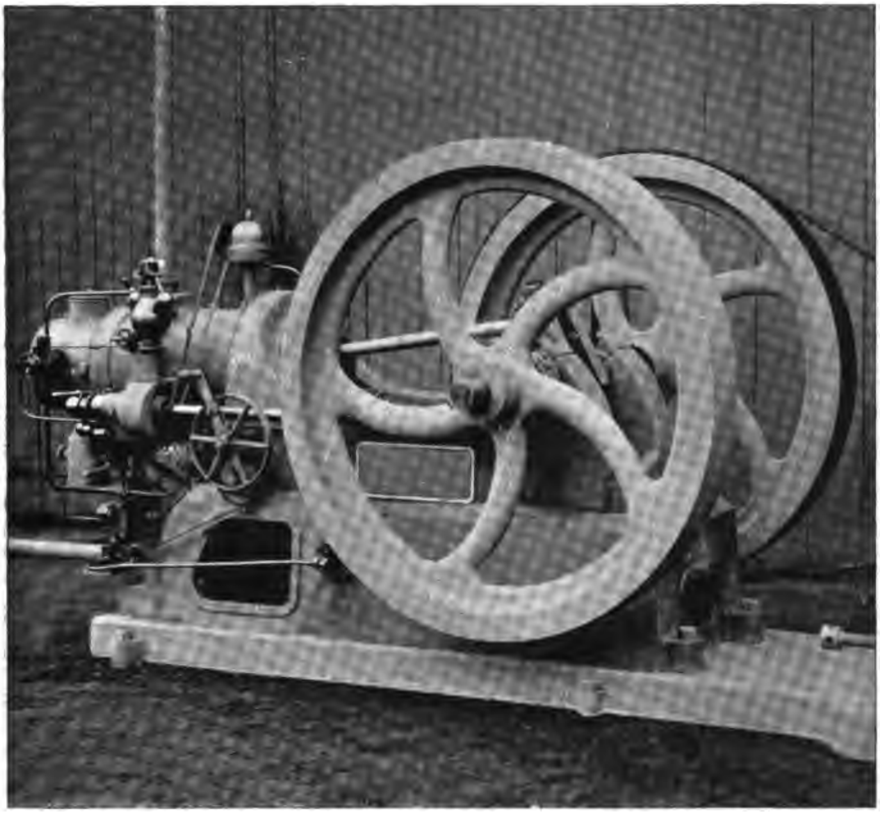


FIG. 63.—STATIONARY HORNSBY-AKROYD ENGINE.

The absence of all flame in this engine, after having started, is a striking feature, and is claimed to make the engine a peculiarly safe one. The engine is turned out in large numbers, and, like other engines of its class, is used for almost every purpose that power is required. The stationary motor is built in sizes of from one and one-half to nineteen actual horse-power, and the portable type, in sizes of from three and one-half to nineteen horse-power. In the portable type that which takes the place of the boiler is a water tank containing water for circulation through the engine cylinder jacket; that which takes the place of a smokestack is an exhaust silencing chamber, and that which takes the place of the fire-box is an oil tank. The outfit is thus remarkably independent and self-sufficing.

A somewhat similar portable oil engine outfit is that shown in Fig. 66, and built by Messrs. Robey & Co., of Lincoln, England. The engine in this case also works on the vaporizer system, oil being injected under pressure into an annular vaporizer chamber, heated only by the heat of combustion in the working cylinder. The governor also acts by determining whether the supply of oil shall go into the vaporizer or back into the oil supply tank. A heavy oil of about 0.85 specific gravity is used, with a flashing point of about 243 degrees Fahrenheit. The water tank contains sufficient water for circulation through the engine cylinder jacket for a whole day, and the oil tank is made large enough to hold a week's supply of oil. Robey & Co. make also a semi-portable engine of the same general design.

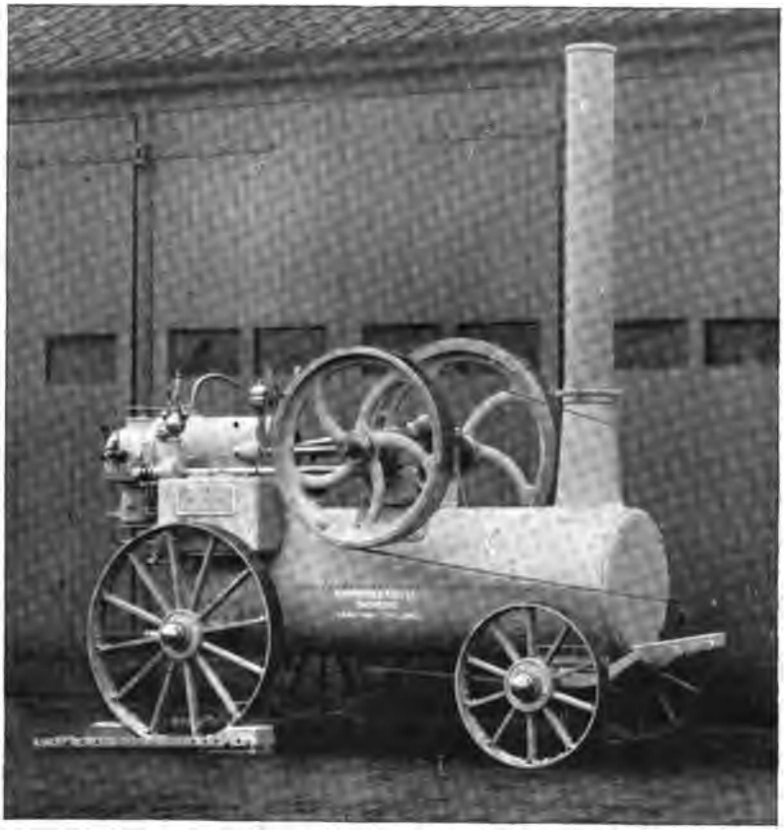


FIG. 64.—PORTABLE HORNSBY-AKROYD OIL ENGINE, BUILT BY RICHARD HORNSBY & SON, GRANTHAM, ENGLAND.

One of the American engines which has made rapid progress during the past few years is that built by the Van Duzen Gas and Gasoline Engine Company, of Cincinnati, O., and of which a number of different forms are shown. Altogether this company turns out seven styles : a simple stationary gas engine, a stationary gas and gasoline engine combined, a stationary gasoline engine, a portable gasoline engine, a stationary gas engine and pump combined, a stationary gasoline engine and pump combined, and a portable gasoline engine and pump combined. The gas and gasoline engine combined, as will be understood, may be used with gas alone, but has a gasoline apparatus attached to prevent any delays in operation should the gas supply suddenly fail. The portable gasoline engine is mounted on trucks, as the illustration shows, and may be used for driving threshing machines, hay presses, etc. The gas and gasoline engines and pumps combined, both stationary and portable, need no special explanation as to the uses to which they are to be put ; the name sufficiently indicates the purposes to which they can be applied. In addition to the types already mentioned, the company also build a marine engine which appears to have met with much favor.

From the illustration of the horizontal stationary engine, Fig. 67, it will be observed that the cylinder, water jacket and pillow-blocks are all cast in one piece, and are supported by a cast-iron base. The four and five horse-power

engines carry one balance wheel, but those from seven horse-power up carry two such wheels. The four-stroke, or Otto, cycle of operation is followed. Between the cylinder and the base is a countershaft, worked by spur gearing from the crank shaft. On one end of this countershaft is mounted a cam for operating the exhaust valve, and on the other end are cams for similarly working the admission and ignition valves. The valves all are of the poppet type, and their stems are fitted with long guides. Figs. 69 and 70, which represent, respectively, side and end elevations of the engine, will help to explain the functions of the main parts.

To begin with, if the engine be below its normal speed, the governor rod D will allow the vibrating stem B to drop into such a position that the toe A will come in contact with it as soon as the rocker arm, marked 4, is raised. This arm begins to raise when the piston is at the end of its in-stroke, or when it is in the same position as that shown in Fig. 69. The cam marked 1, it will be noticed, is first about to come in contact with the cam roller 5 and the rocker arm 4. When it actually comes in contact with it and raises the arm 4, the toe A will be depressed, come in contact with the valve stem B, and open the admission valve C. By the time that the crank has come into the position B, corresponding to the end of the out-stroke of the piston, the valve C is again shut. The cams 1 and 3, working, respectively, the admission and the exhaust valves, are so designed as to

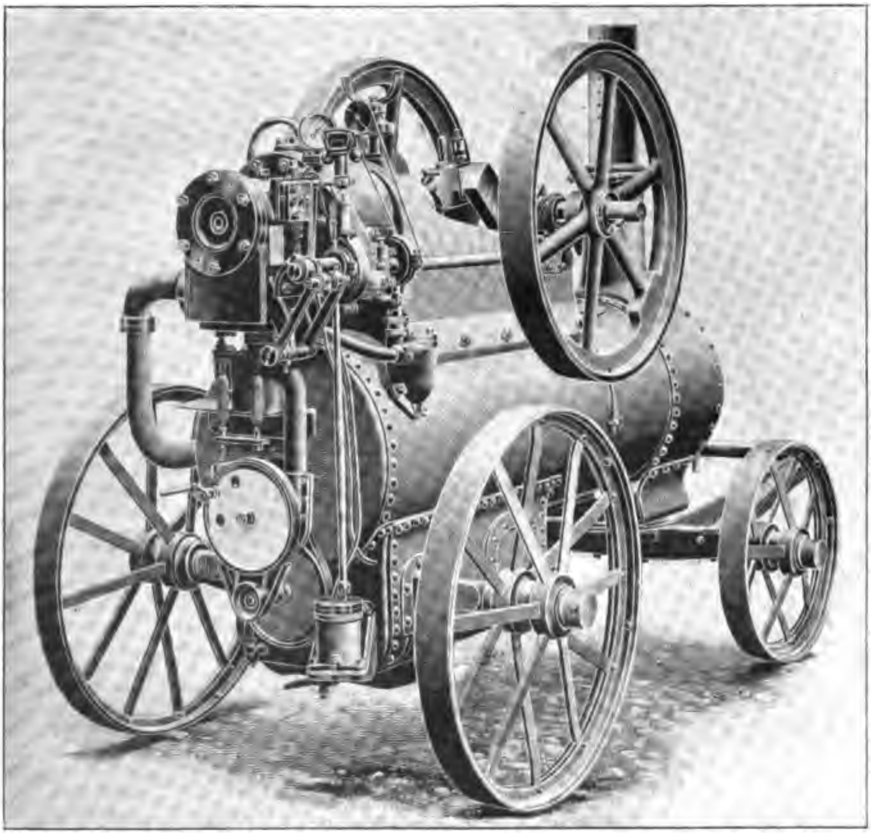


FIG. 66.—PORTABLE OIL ENGINE, BUILT BY ROBEY & CO., LINCOLN, ENGLAND.

effect quick opening and shutting of valves, and also to keep them wide open during a large portion of the piston travel.

During the next half-revolution of the crank, from the position B back again to the position A, the mixture in the cylinder of the engine is compressed, and as the crank passes the inner centre, the cam, marked 2, comes in contact with the lower end of the two-armed lever E, and though it opens the other end of the cam shaft opens the exhaust valve, and allows it to close again when the crank finally resumes its initial position A. This completes a full working cycle, and everything is then in readiness to resume the same series of operations.

The end elevation, Fig. 70, shows, among other things, a vertical section of the carburettor. It consists of an iron casing with an inner tube through which the air necessary for the working charge enters. On top of this inner tube is seated a flange valve. As the air enters, it necessarily raises this valve which, in turn, raises the fluted stem of the check valve above it. The gasoline is in the chamber above this valve, and as soon as the valve is lifted the gasoline flows down inside the flange valve and out through the laterally disposed holes, as indicated by the arrows. Thence the gasoline flows

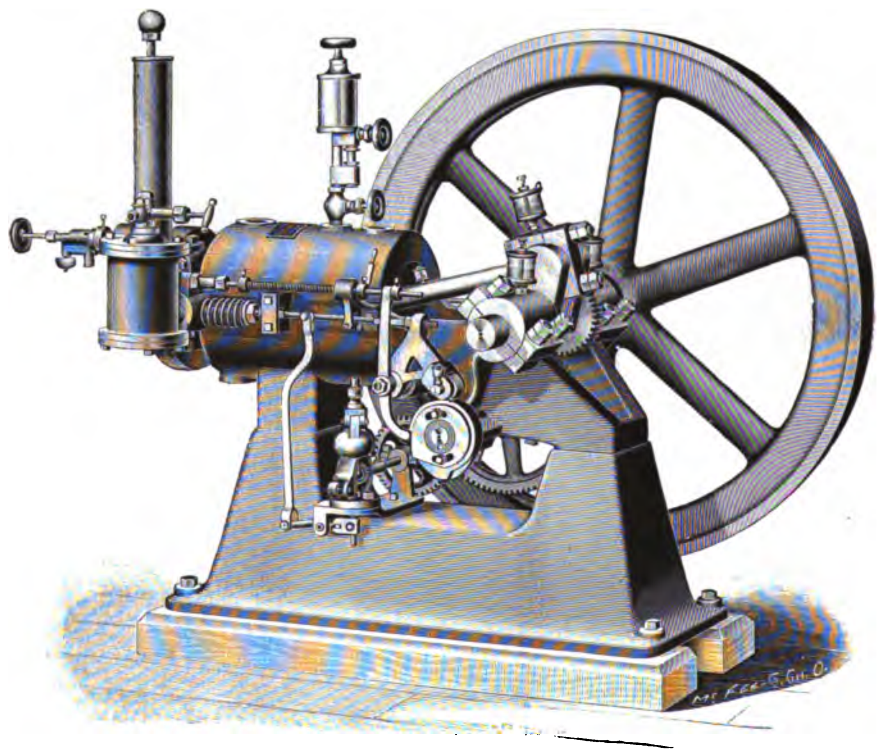


FIG. 67.—STATIONARY ENGINE, BUILT BY THE VAN DUZEN GAS AND GASOLINE ENGINE CO., CINCINNATI, OHIO.

the ignition valve N. The opening ot this valve allows part of the explosive mixture from the cylinder to pass up into the ignition tube O. On the end of this tube is a ball H which is said to serve as a cushion, and to dispose of the waste gases which accumulate in the ignition tube. The mixture, being ignited, again forces the piston forward, bringing the crank once more into the position B. By this time the cam 3 on

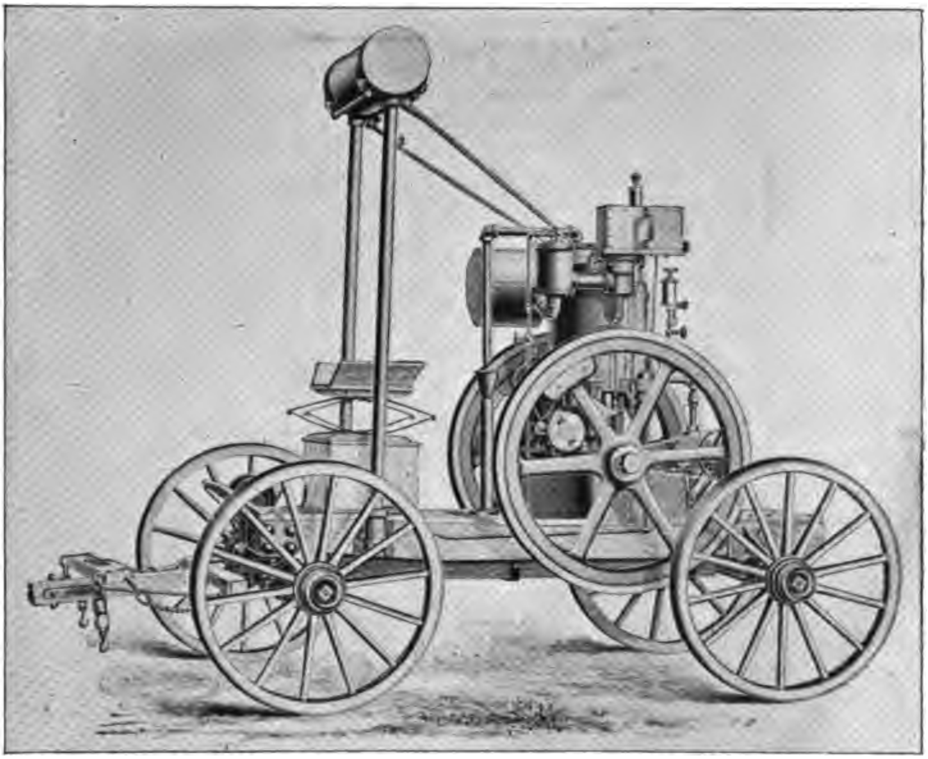


FIG. 68.—PORTABLE VAN DUZEN ENGINE.

over the edges of the air valve and is caught up by the air current flowing downward through the inner chamber and through a number of gauze rings, being vaporized on its way. It will be observed that no gasoline is allowed to enter the carburettor until the engine calls for it. From the carburettor the mixture goes immediately to the cylinder through the admission valve. Should any premature explosions occur, they would have to take place in the carburettor, and this is made strong enough to withstand them. As soon as the admission valve on the engine cylinder is closed, the air valve in the carburettor drops back on its seat, thus, in turn, allowing the gasoline check valve to drop back also, and effectively shutting off the gasoline supply. The gasoline tank necessarily is placed above the level of the top of the carburettor in order to allow the gasoline to flow to the latter by gravity.

The main features of the governor with which the engine is supplied are shown in the side elevation. The governor is worked from the crankshaft by intermediate gear wheels, and can be set to run at any desired speed. Changes of speed can be easily and quickly made.

Another engine of American design, more recently put on the market, is the Sintz engine, shown in Fig. 81, and built by the Sintz Gas Engine Company, of Grand Rapids, Mich. It is of the vertical type and is turned out both for gas and gasoline use. When gasoline is to be employed, the engine is provided with a small pump and is connected with a gasoline supply tank conveniently located. The operation of the engine is substantially as follows: When the piston makes its first upward stroke of the working cycle, it draws a charge of air into the crank casing with which, as will be noticed,

the engine is fitted. On the following downstroke, and when near the end of its stroke, the piston passes a port in the side of the cyiinder which communicates with the crank chamber. Just as the piston begins to open this port, the small gasoline pump (when gasoline is used) begins its downward or discharge stroke, causing the gasoline to pass into the port in the form of fine spray, and it finishes its stroke at the same time that the main piston this time performing a working stroke. On reaching the end of this stroke an exhaust port is uncovered, about opposite the transfer port already mentioned, and the waste gases are enabled to escape before the fresh charge is transferred to the cylinder. The design is such that an impulse, or explosion, takes place at every revolution while gasoline or gas is supplied. The supply of the oil or gas is controlled by the governor by its action on either the

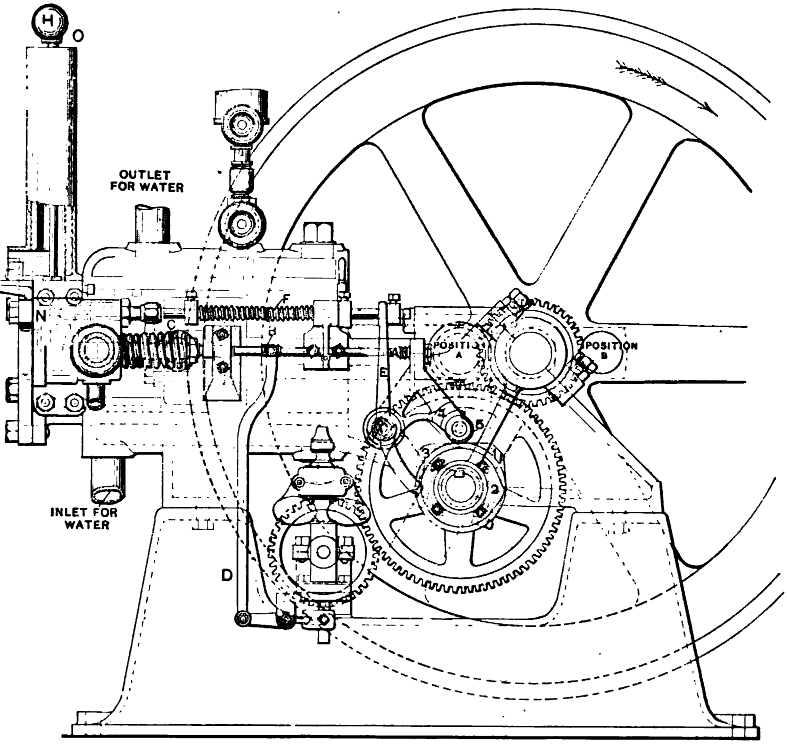


FIG. 69.—SIDE ELEVATION OF A HORIZONTAL VAN DUZEN ENGINE.

completes its downward stroke. In the meantime the air, which has been slightly compressed in the crank chamber, is rushing through the port, and is deflected to the top of the cylinder, carrying the gasoline with it, and forming an explosive mixture.

The piston, on its next upward stroke, compresses the charge in the upper end of the cylinder where it is ignited electrically at the proper moment and drives the piston down again, gasoline pump or on the gas valve, depending upon the kind of fluid used.

A special marine engine outfit is made by the builders, the engine itself being of substantially the same design as that shown. Both the marine and the stationary engines are made in sizes of from one to fifteen horse-power.

The "Forward" gas engine, an English design, built by Messrs. T. B. Barker & Co. of Birmingham, is shown in Figs. 76 and 77, the former repre-

senting the type followed in engines up to nine horse-power, having a single fly-wheel, while the latter shows an engine with two fly-wheels of the kind turned out in sizes of from twelve to twenty horse-power. The engine follows the Otto cycle in its operation, working ordinarily, with one explosion in every two revolutions, the number

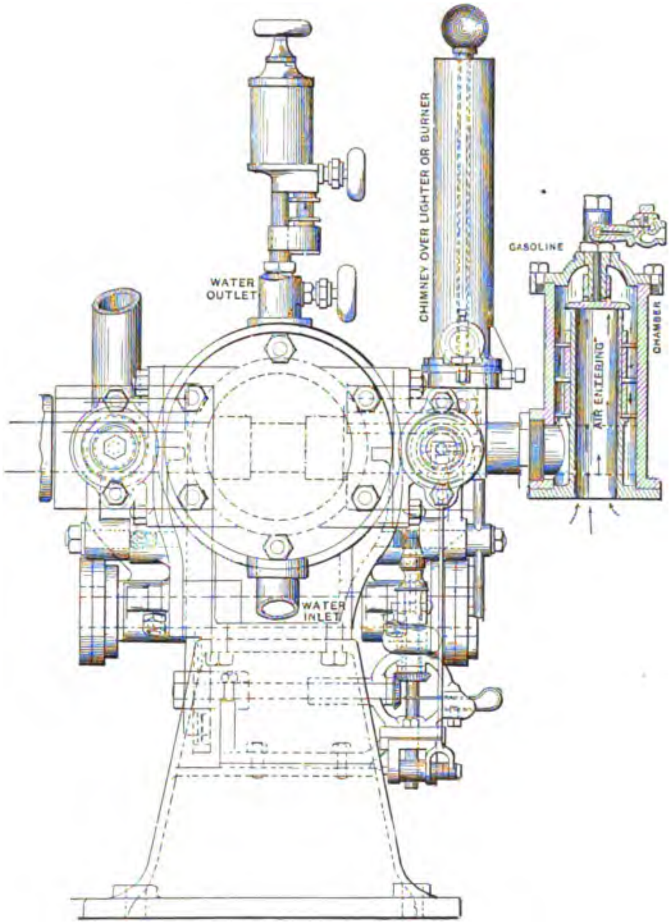


FIG. 70.—END ELEVATION OF VAN DUZEN ENGINE.

of explosions, however, being reduced, as in many other engines, by the action of the governor when the engine is running with a light load. The principal feature of interest in the engine is the application, to the larger sizes, of a starting gear invented by Mr. F. W. Lanchester, and which adds nothing to the bulk or complexity of the engine, at the same time answering its purpose admirably, and making the engine as easy to handle as an ordinary steam engine. A sectional view of this starting gear is given in Fig. 79 The method of operation of the attachment is extremely simple.

Gas is allowed to blow into and through the cylinder until an explosive mixture is created within it, the condition of the mixture being judged by the color of the flame produced by allowing it to blow through an external pilot jet. At the right moment the gas is shut off and the flame strikes back through the blow-off cock, causing an

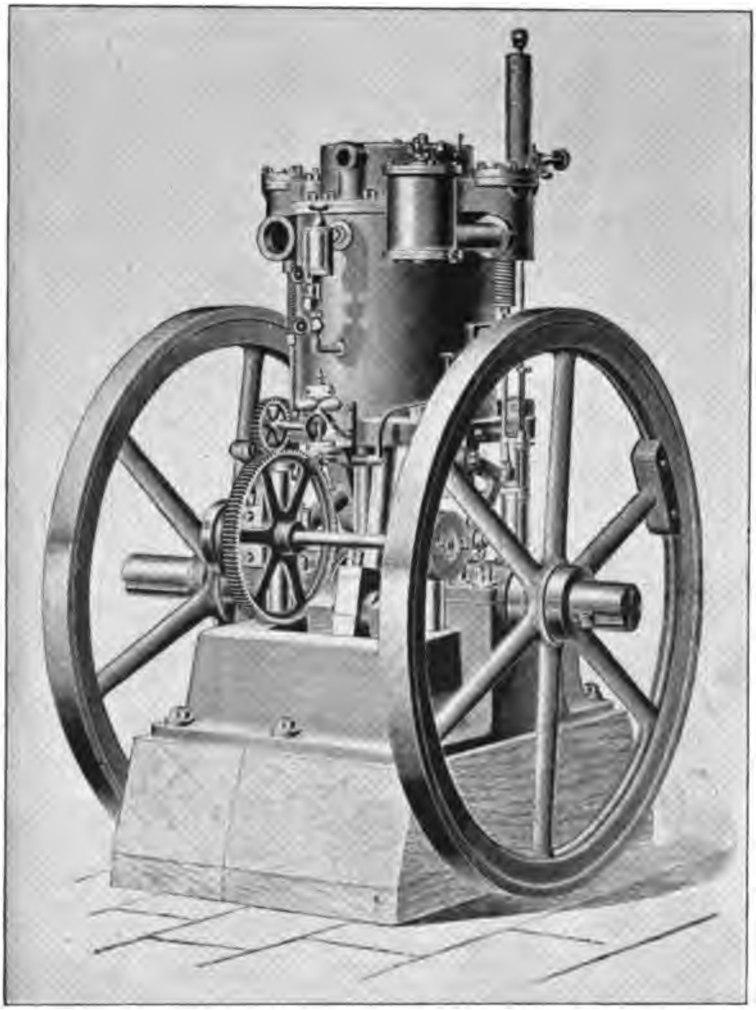


FIG. 71.—LARGE SIZE VERTICAL VAN DUZEN ENGINE.

explosion which starts the engine. The back stroke of the piston exhausts the gases, and the next stroke draws in a charge in the usual way; it also sucks in the pilot flame through the blow-off cock, and fires the charge, the engine thus temporarily working on the Lenoir cycle, explained in the first paper, with an explosion at each revolution. Under these conditions a speed of 120 revolutions per minute is gained in a few seconds. A certain speed, less than 120 revolutions, however, is needed to insure a compressed charge exploded by an incandescent tube. When the requisite speed is attained, the blow-off is closed, and the cam set to exhaust every second revolution; the engine then works compressively and fires its charge from the hot tube. In the diagram *j* is the gas nozzle, *f* the blow-through cock containing a lightly loaded non-return valve which closes at the explosion, *d* the outlet, *c* the pilot flame, *h* the gas pipe, *e* the exhaust valve, and *m* the exhaust cam.

It is interesting to note that besides having been applied to the "Forward"

gas engines for some time past, the apparatus has also been used with success on engines of other makers.

The Trent gas engine, shown in perspective in Fig. 72, is a single acting engine, receiving one impulse for every revolution, and is made by the Trent Gas Engine Company, Limited, of Nottingham, England. Sectional views of the cylinder are given in Fig. 75. The cylinder, as shown, is of two different diameters and contains the double-headed piston B D. When this piston makes its outstroke, gas and air are drawn in through a simple steel valve E. On the instroke of the piston this valve is closed mechanically and the mixture of gas and air is forced through the valve O into the explosion chamber M, where it is compressed, driving before it the exhaust gases remaining from the previous explosion which escape through the valve R, and is then ignited. The resulting explosion drives the piston outward, and the acquired momentum of the fly-wheel performs the next instroke. The valves are worked by cams on the crankshaft, and the gas supply is regulated by a hit-and-miss device controlled by a centrifugal governor. Firing of the gas and air charge is effected by a tube igniter. The engine is built in sizes of from one-half to 100 horse-power, and has done some good work in electric lighting.

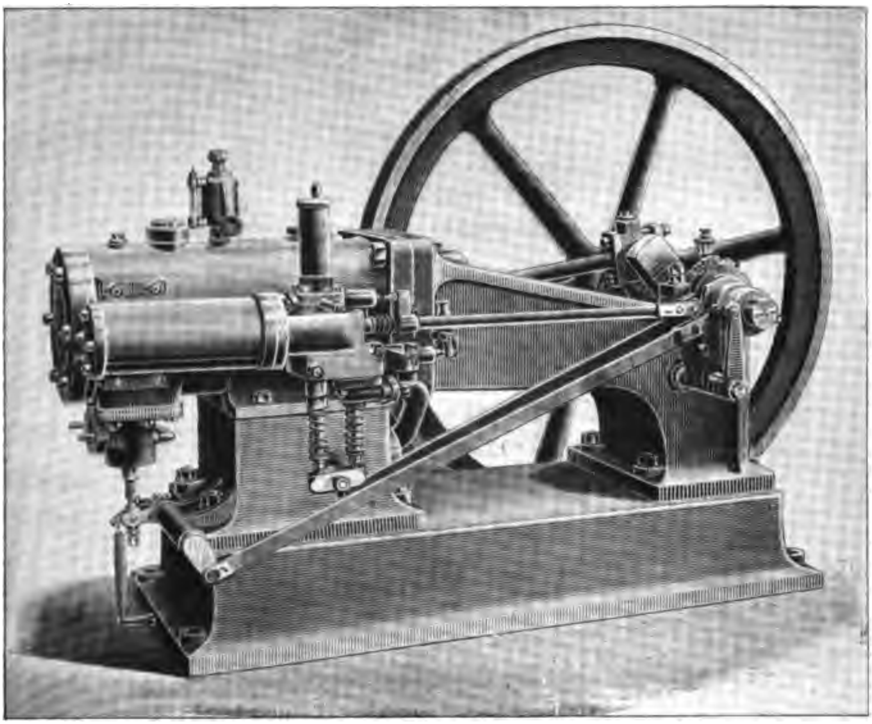


FIG. 72.—THE TRENT GAS ENGINE, BUILT BY THE TRENT GAS ENGINE CO., NOTTINGHAM, ENGLAND.

A gas engine, somewhat unusual in appearance, reminding one of a steeple compound steam engine, is made by the Hicks Gas Engine Works, of Cleveland, O., and is shown in Fig. 80. The two cylinders are set in line, one above the other, and are arranged to work alternately, so that practically there is one effective impulse for every revolution of the crankshaft, the Otto working cycle being followed in each

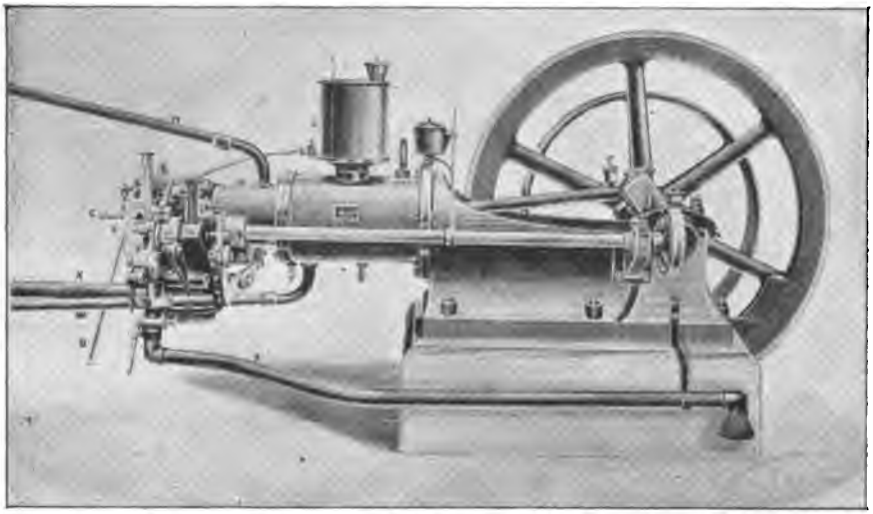


FIG. 73.—THE ROCKET PETROLEUM ENGINE, BUILT BY ROBERT STEPHENSON & CO., NEWCASTLE, ENGLAND

cylinder. Compared with a single cylinder gas engine, therefore, we find in this case, for the same sets of conditions, that the power of the engine is doubled, while the additional weight consists only of the weight of one cylinder and its piston. Another advantage of the two alternately working cylinders is found in the circumstance that the weight of the fly-wheel may be reduced considerably without unfavorably affecting the regular running of the engine. The design and construction of the engine are very simple and call for little explanation. The illustration, in fact, tells almost the whole story.

The amount of the explosive charge admitted to the cylinders is controlled by a governor as in a steam engine, the governor either throttling the supply or opening the valve wide, according to the demand for power. All the

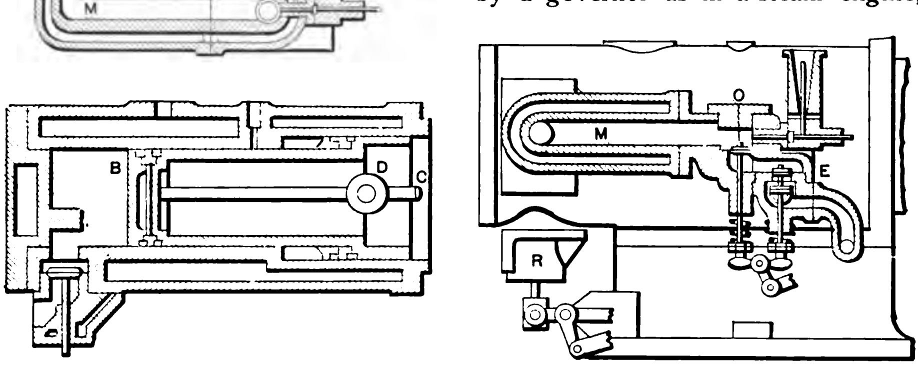


FIG 75.—SECTIONAL VIEWS OF THE TRENT ENGINE.

valves used are of the lift type. The exhaust valves, shown on the left of the cylinders, are worked by rods and tappets, and these, in turn, are moved by suitable cams carried on a small shaft in back of the engine frame. The cam shaft is driven from the main shaft through intervening gear wheels of such diameters that its speed is reduced one-half. Gasoline as well as gas may be used in operating the engine, the former, however, naturally calling for the addition of a carburetting apparatus of some kind.

A petroleum engine, which by its name as by its builders, recalls the early days of the locomotive, is shown in Figs. 73 and 74. It is called the "Rocket," and is made by Messrs. Robert Stephenson & Co. of Newcastle-on-Tyne, England, under the patents of E. Kaselowsky. The engine works on the well-known four stroke cycle. The governing arrangement is such that the supply of explosive vapor is entirely cut off when the speed of the engine runs above the normal, and with the exercise of the governor in this way a lever acts simultaneously to relieve the compression of the waste gases in the cylinder, thus helping to make the speed more regular. Sufficient oil for a day's work can be stored in a tank fixed above the cylinder, from which it is allowed to flow by gravity into a lower receiver. In this latter there is a float regulating the supply. The firing of the charge is effected by an

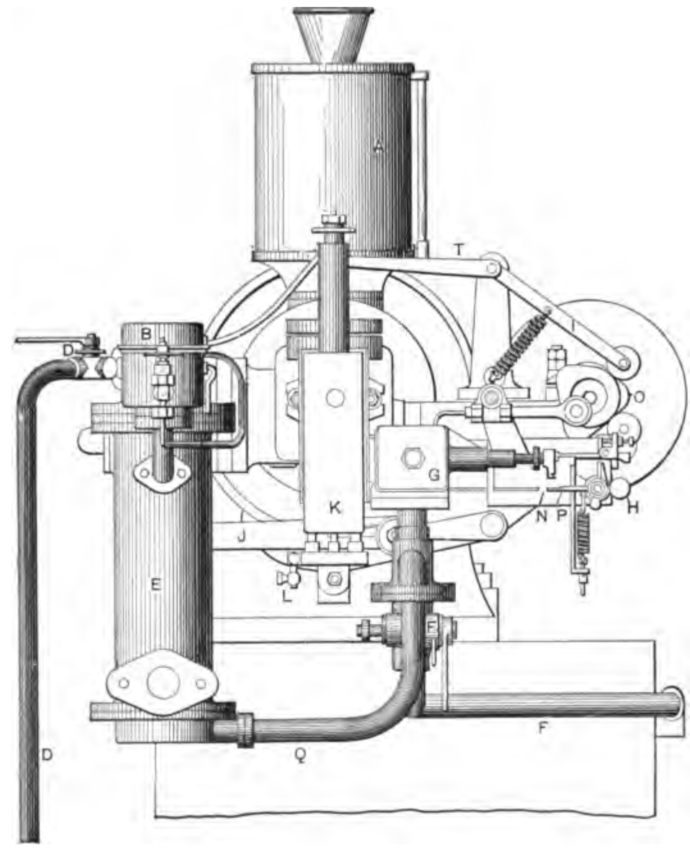


FIG. 74.—END VIEW OF "ROCKET" OIL ENGINE.

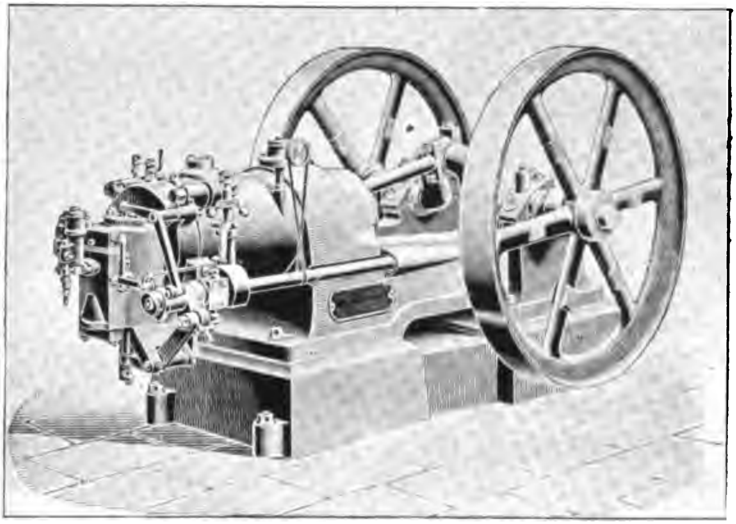


FIG. 77.—DOUBLE FLY-WHEEL "FORWARD" ENGINE.

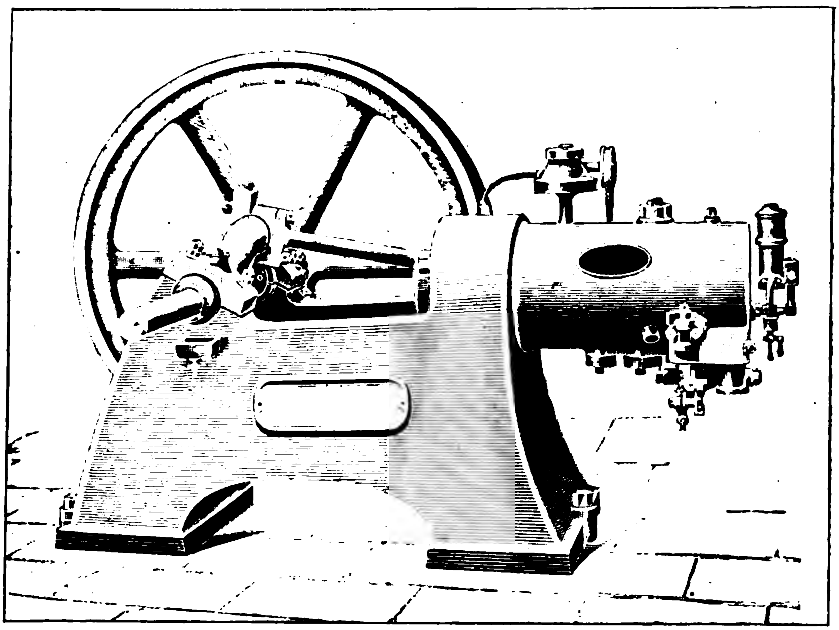


FIG. 76.—THE "FORWARD" ENGINE, BUILT BY T. B. BARKER & CO., BIRMINGHAM, ENGLAND.

The sprayed oil is converted into vapor in its downward travel through

FIG. 78.—VERTICAL "FORWARD" ENGINE.

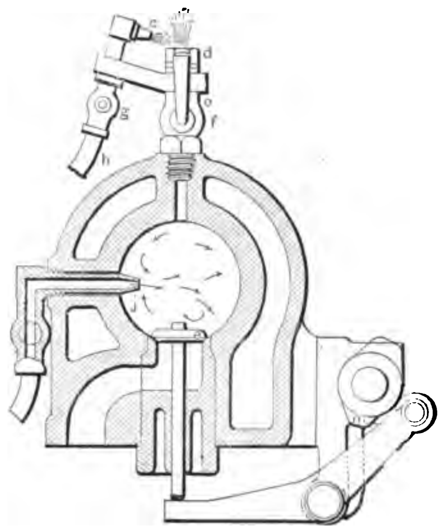


FIG. 79.—LANCHESTER'S STARTING GEAR.

ignition tube with a timing valve worked by the lever I and cam O. Compression in the cylinder is diminished by keeping the exhaust open when the engine is being started, and one man can, therefore, easily turn the engine over. The oil used is ordinary lamp oil.

From the oil tank A the oil, as just stated, flows to the lower receiver B, and from the latter it passes through the regulator and into the top of the vaporizer E. In this the oil is sprayed by an air current and passes through tubes in the vaporizer, which forms an enlargement of the exhaust pipe. The bottom of the vaporizer is heated by a lamp flame for starting, but after the engine is once in operation the exhaust gases perform the heating. The main air admission pipe is marked F and is provided with a regulating cock, F'. Air is also admitted to the vaporizer through the pipe D, which, similarly, has a regulating valve.

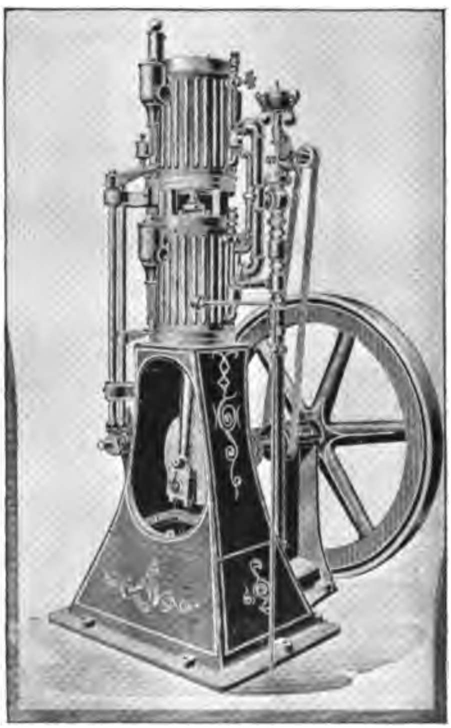


FIG. 80.—THE HICKS GAS ENGINE, BUILT BY THE HICKS GAS ENGINE WORKS, CLEVELAND, OHIO.

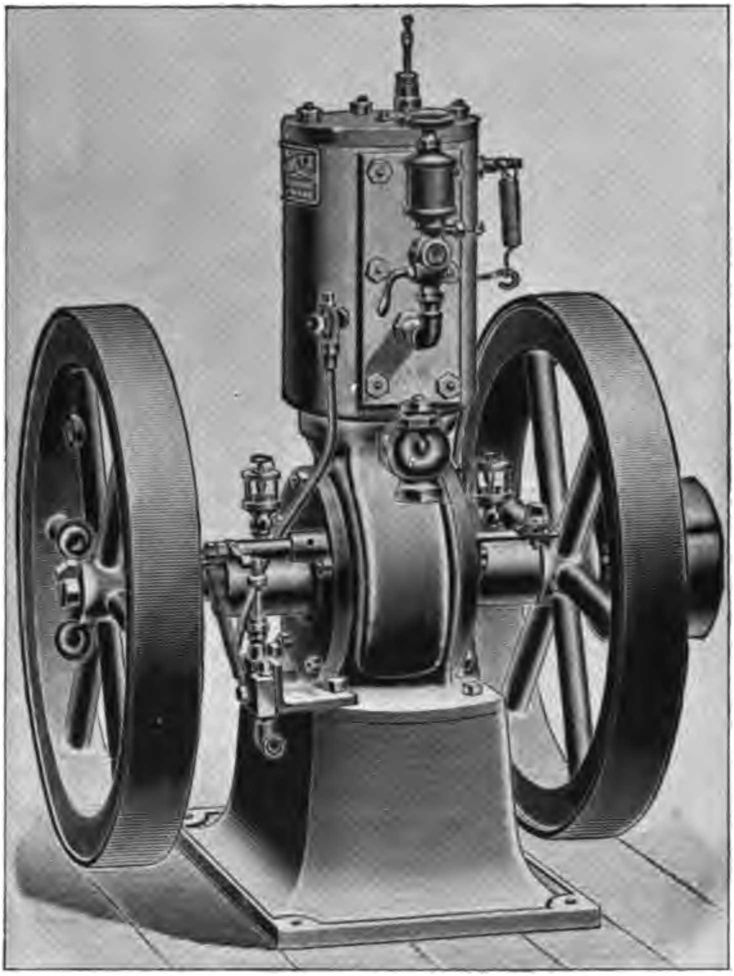


FIG. 81.—THE SINTZ ENGINE, BUILT BY THE SINTZ GAS ENGINE COMPANY, GRAND RAPIDS, MICH.

the vaporizer, and, in addition to the air of the spraying current, takes in a further supply through the pipe D. It then passes into the pipe issuing from the bottom of the vaporizer and joins the main air inlet pipe at a point above the cock F^1. From this point it finds its way into the cylinder of the engine through a valve, G, controlled by the governor H, trip P and notch piece N. When the engine runs too fast the spindle of the admission valve G is missed, and another valve, not shown in the illustration, is opened to allow the gas contents of the cylinder to escape. The exhaust valve lever is shown at J; W and W^1 are water circulating pipes for the cylinder jacket, and X is the exhaust pipe. The ignition tube is surrounded by a case, K, and L is the oil and air admission pipe for the heating flame. The engine is made in sizes of from one to ten horse-power.

(To be continued.)

THE LIFE AND INVENTIONS OF EDISON.*

By A. and W. K. L. Dickson.

Ninth Paper.

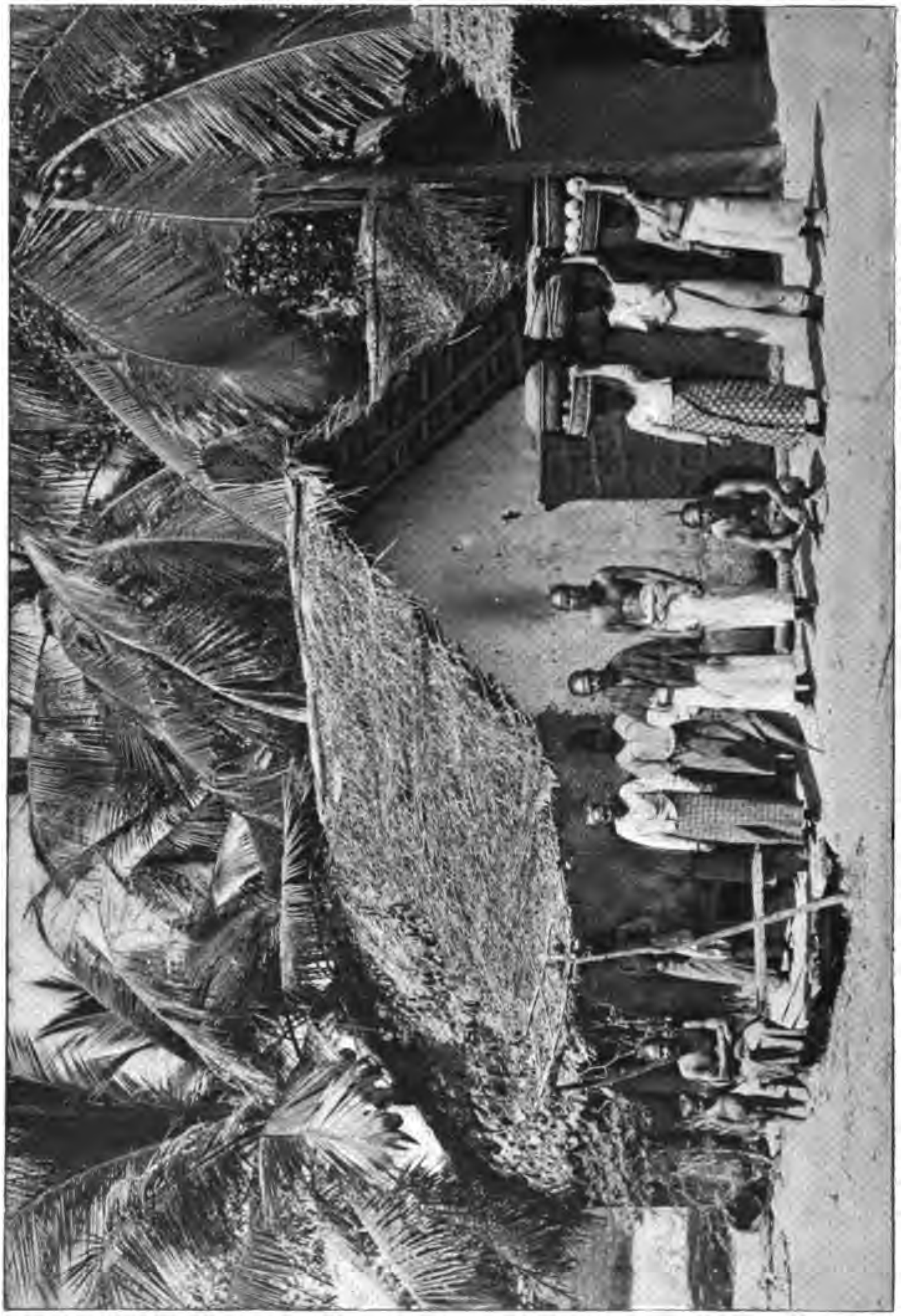
THE searches for suitable bamboo fibre for electric lamp filaments, made in Ceylon, the Indian peninsula, and adjacent countries, were admirably conducted by Mr. Ricalton, the well-known explorer and school principal of Maplewood, N. J., and established an intelligent basis for later discoveries. Mr. Edison's discriminating power in the selection of his emissaries was most felicitously illustrated in this instance. To an exhaustive knowledge of natural science, Mr. Ricalton added unusual powers of observation, invincible courage, swift powers of decision and an unquenchable love of travel. The latter attribute was observable even in early youth, when his scant economies were invested in a steerage trip on a lake propeller to Michigan. Since that initial voyage, it is estimated that he has covered 45,000 miles, exclusive of the trip taken in Edison's interests, and despite the attractions of an ideal home and an equally ideal family, the responsibilities of a pedagogic career, and other trifling claims, he is, as we write, engaged in another scholarly pilgrimage, which will be doubtless as fruitful in historic and scientific results as its predecessors. Mr. Ricalton furnished the following reminiscences of his researches for Edison :

"On an afternoon in January, 1888, while prosecuting the usual routine of the schoolroom, a recitation was interrupted by a rap at the door, in answering which a messenger placed in my hand a letter from Thomas A. Edison, which requested me to meet him a few hours later on the same afternoon. A communication from such a source was, of course, a great surprise, and if anything could exceed my surprise, it was my curiosity as to what the 'Wizard' could want of one in the pedagogic line, whether possibly a tutor and disciplinarian for the junior Tommie, or what.

"However, at the hour designated, I was amid the whirr of the great laboratory, and escorted by the very courteous Mr. ——— into the presence of Mr. Edison, whose cordial greeting and simple manner quite removed the trepidation that possessed me on being presented to genius. 'You like travel, I believe?' was his first observation. Abbreviating my words to his evident wish to dispatch business, I replied 'Rather.'

"'I want a man to ransack the world for a fibre ; how would you like to undertake that?' he continued. 'That would suit me,' I answered. 'How soon could you start?' was his next query. I stated that I must get the permission of the Board of Education to vacate my position as principal of the school, the board must secure a substitute, and then I would require a little time for preparation. 'Oh, I want you to start to-morrow,' exclaimed the great electrician. 'But, Mr. Edison, I must have a little time ; you want me to search the world—the world is large, and I have buttons to sew on.' 'Well,'

* Began in November issue.



HUNTING FOR FIBRE.—A CINGALESE VILLAGE.

he continued, 'it is somewhat of an undertaking. It may take you three years, and you may succeed in six months; so lose no time in securing a leave of absence, take a week or two for preparations, come to my laboratory daily during that time for experimentation; when you have concluded your experimental work, go into the library and study the flora of the tropics; learn the habits of every specie of bamboo, and of fibre-plant; make for yourself maps of the tributaries of the Irrawady and Brahmaputra rivers, and other places you will have occasion to search. In the meantime I will have made for you a complete outfit of tools for testing the fibrous products of the tropics.'

"This summarizes substantially my first interview with Edison concerning my explorations for fibre. A very obliging Board of Education gave cheerfully the necessary leave of absence; two weeks were spent in Mr. Edison's laboratory and library, and on February 22, 1888, I sailed for India via Liverpool, London, Brindisi and Suez Canal, reaching Colombo in Ceylon, on April 1. Three and a half months were spent in that Eden of tropical luxuriance, where nearly 100 different species of bamboo and palms were found and tested.

"I enlisted in my service native Cingalese guides noted for their woodcraft and their knowledge of the bamboo family, in which I had most hope of finding the fibre-desideratum. In these searches I visited every part of the island, often sleeping in the dense jungle by a camp-fire where insect pests are multitudinous and merciless; the most revolting specimen of the latter is the land-leech, much smaller but resembling the medical leech, twenty of which, mostly filled with blood, I removed from my body on one occasion, after emerging from the jungle.

"The most magnificent species of the bamboo family, although it is a native of Burmah, is found in Ceylon. It is called the giant bamboo, and clumps of from 100 to 200 may be seen reaching to a height of 120 feet, and measuring from ten to twelve inches in diameter.

"From Ceylon I crossed to India, and proceeded from Cape Comorin at the extreme south, to the Himalayas, visiting on my way northward the different bamboo regions, using the same methods as in Ceylon to obtain samples of every species, sometimes offering to the natives premiums for new specimens. After exploring the jungles in the vicinity of Pondicherry, Bangalore, Madras, Bombay and Delhi, I tested all the different fibre-wood at the base of the Himalayas; then I worked my way into the high lands as far as the Sutlej river, where civilization is so attenuated that the only means of navigating the river is on inflated bullock skins.

A NATIVE BARBER.

"From the Sutlej I descended to the plain and followed the Ganges to its mouth. On the north of Calcutta I again ascended the Himalayas to an altitude of 6000 feet, where I found some fine specimens of the bamboo family. Descending the Himalayan range again, I entered Assam, and ascended the Brahmaputra several hundred miles, testing everything en route, then returning to Calcutta via Dacca.

"From Calcutta I sailed to Rangoon in Burmah. From Rangoon I followed the Irrawady to Mandelay, using the same methods in obtaining and testing fibre samples at the different points. From Burmah I followed the Malayan coast to Singapore, where I again collected from the surrounding country, tested and proceeded to Hong Kong; thence to Canton, where I secured specimens of every variety. I did the same in Japan, where the search was much simplified by the complete collections of bamboos in the Botanical Gardens and Museum at Tokio.

"When I left the laboratory, Mr. Edison placed in my hand a sample of bamboo about which he said, 'If you find as good as that I will be satisfied.' In two localities of the tropical belt through which I had passed, I found fibre which stood a much higher test, as a carbon, than that furnished as a satisfactory sample by Mr. Edison, but I have since learned that its splitting qualities are not so good. My search was intended to include Java, Borneo and other East India islands; but, with perfect confidence in the sufficiency of two different fibres already found, I turned my course from Japan toward San Francisco, and reached home on the following 22d of February.

"On my return, Mr. Edison, I was informed, was using an artificial carbon which he then expected would supersede the bamboo, and whether any practical use has ever been made of the fibres found I have never learned. The first time I met Mr. Edison after my return, I shall not soon forget, as showing how ordinarily important things are looked upon as trifles in a mind so fully occupied. I had spent a year in an unusually hazardous search, embracing a circuit of the globe, and entailing an expense that would be a fortune to many a toiler. He was passing through the laboratory on his incessant supervisory work; he extended his hand, smiled, and with a brief 'Did you get it?' hurried on to the thousand and one exigencies with which his wondrously busy life is filled.

"When I set out on my journey of discovery, I felt it an honor to serve one whom I have learned to regard as the most widely known man in the world to-day. In all my journeyings I have been many times astonished to find his name so well-known; even the unlettered natives of half-civilized countries have learned to associate his name with the electric light. My donkey-boy in the streets of Cairo was endeavoring in broken English to tell me something about the Khedive, whereupon I asked him the name of our American Khedive. He shook his head to tell me he did not know. I mentioned the name Harrison, but he did not recognize it; then I mentioned Edison's name; he smiled cognizantly and drawled the name —'Ed-ee-sone' while pointing up to an electric light before the hotel. Only a few weeks ago I mentioned the name to my courier in Morocco, whereupon he quickly proceeded to offer his knowledge of the man. Edison's name is truly a household word to the ends of the earth."

The bamboo of which the inventor made final selection was discovered shortly afterward by Mr. William Moore, under whose auspices a tract of land in northern Japan was purchased and placed under charge of two native farmers. Over $100,000 were expended by Mr. Edison, in the course of his investigations, and few portions of the globe were left unexplored.

The structure of the lamps, in the meanwhile, had undergone important modifications. In the fall of 1879, the lamp presented the shape of a nearly globular bulb with an elongated neck, and filatures which extended to the inside of the lamp, the platinum leading-in wires were sealed to the summit of the interior, the tips on the globe were pointed and hollow, and platinum clamps were utilized. Within the next two or three months the shape of the globe had again been altered and was considerably enlarged, in deference to the belief that the defective burning power was due to the contracted dimensions of the enclosing chamber. At this point the comparative elimination

EXPLORERS CROSSING A RIVER ON INFLATED BULLOCK SKINS—ONLY METHOD OF TRANSPORTATION.

of air was secured, although the sealing of the glass tops was rough and inefficient. Later in the spring of 1880, a species of white German glass was utilized at the junction of the platinum wires with the glass, for the purpose of securing a more perfect seal. This was discontinued in the fall of the same year, and the shape of the globe was modified to meet the requirements of the bamboo filaments to which we have alluded. In the winter of 1880, the lamp had reached greater durability, the supplemental tips at the summit were shortened, and the platinum leading wires introduced through the glass interior were solidified and rendered more compact by being compressed into shape while hot and malleable. Other lamps, constructed at this period, show novel features, such as the use of a wooden socket—and the wires coming from the lamp are soldered to contact rings, insulated from each other, one plain and the other threaded to facilitate making contact in the lamp socket. In January of 1881, tests were made, with a view to substituting the cheaper metals, silver or copper for the platinum used in the construction of the clamps, and the contact between the carbon filament and the platinum wires was materially improved. Further changes followed in the substitution of plaster of Paris sockets instead of wood, in the heightened resistance of the bamboo filament, and the superior symmetry of the general proportions. Between this type and the perfected lamp of the present day, there are fewer points of dissimilarity than between any other of the several forms of evolution. The difference consists mainly in the use of carbon paste, in the omission of the supplemental tip, in the attenuation of the filament and in the substitution of a brass contact plate and threaded brass ring for the contact rings alluded to above. The spring of 1881 gave birth to the first permanent record of electric light, in the shape of an incandescent lamp, which lasted 1589 hours, at a height of sixteen candle-power.

The strain of continuous thought and manual exertion attendant on the production of the electric light and other inventions was lightened in Edison's own characteristic fashion, for, although unsparing to himself, he was possessed of a kindly consideration for those less mentally and physically endowed. It must be confessed that during the periods of inspirational insanity these humane scruples were generally lost sight of, but no sooner were the desired results attained than a healthful

reaction set in, and the entire force would be dispatched on what Samantha appropriately terms "a pleasure exertion." To this end Edison was wont to charter a certain brick sloop, in harborage at Woodbridge, supplying her with provisions, fishing tackle, and whatever might be supposed to contribute toward the building up and relaxing of the human system. This cosy and capacious craft became the scene of piscatory exploits many and marvelous, in which the promoter of the enterprise bore an illustrious part. The feeling of unbent jollity which reigned on those occasions received a decided impetus from the chief's presence, for Edison knew how to throw himself into these harmless dissipations without impairing his legitimate authority. His bonhomie, kindly humor and unostentatiousness were calculated to call forth the best qualities in those around him, but of all his attributes, none appealed so forcibly to the men as the master's efforts to shield them from adverse criticisms. On one occasion, an associate of Mr. Edison was called upon to give the bearings of some intricate electrical problem before an august board of inquiry, and in so doing was betrayed into several inaccuracies. These were taken exception to by the members, but the general verdict was waived in consequence of Mr. Edison's authoritative support of his protégé. No sooner, however, was the room cleared, than the chief turned to the young man with the remark—"Now here, you were wrong about that affair. I saw that at a glance." "You did, Mr. Edison," rejoined the other, amazed. "Then why did you endorse me?" "Because I wasn't going to let those duffers have the satisfaction of crowing over you, if I could help it," was the reply.

Mr. Edison indulges in no harsh methods to secure obedience, and the most timid neophyte meets with an easy and kindly simplicity which invariably has the effect of reviving his paralyzed faculties. Intelligent ignorance has nothing to fear from the master's superior abilities, but pretension and finicky elegance are certain to call forth Edison's powers of sarcasm, and a demure assumption of the discarded duties.

A dudish applicant, with an overweening sense of his own self-importance, once refused to perform some of the rough work attendant on an important experiment.

"Why should we only toil, the roof and crown of things?"

he demanded, in substance, if not in phraseology. Edison indulged in no scathing rebukes, nor did he abruptly dismiss the applicant, as a less gifted psychologist would have done. He simply apologized with elaborate courtesy for having taken the liberty of suggesting manual labor in connection with so distinguished an aspirant for electrical honors, and, rolling up his sleeves, plunged into the work himself, shrinking from neither dirt nor fatigue in the prosecution of his object. The lesson was efficient and never required to be repeated. The youth was possessed of some saving grace under his spurious elegance, and the example of his chief bore lasting results in his subsequent career.

Menlo Park was in the early eighties a spot not unworthy of that class of students whose energies are engaged in the perennial search for novelty. There were strange doings in that den of scientific lunatics, scenes which must have drawn tears from the eyes of our Puritan ancestors, and awakened the virtuous indignation of those dwellers in Wormeldingen, where "the homes are washed and waxed, and the streets brushed and dusted, till not a straw lies about, and the trees have a combed and brushed appearance, and do not dare to grow a leaf out of its place." If, during the progress of some pregnant electrical problem, a casual visitor had stepped in, his eyes would have rested on the unhallowed spectacle of a great workshop in the last stage of inartistic disorder; men lying in attitudes more suggestive of ease than elegance, taking what sleep they could on tables, benches and floor; others plying their labors

with tense brows and bloodshot eyes, while the master was calmly slumbering amid the general turmoil, his unkempt head supported by a stick of wood, round which an overcoat was carelessly flung. Thirty men were usually at work in this room, sometimes for forty and sixty hours at a time. These abnormal tests of endurance were generally enlivened by choice selections on the organ, presumably of that order which prompted the paraphrase on Collins' "Ode to the Passions,"

"When music, heavenly maid, was young,
It's then she oughter had been hung."

Jokes scintillated, yarns were spun, songs and recitations fluent, rose-colored vapors which buoyed up Time's laggard pinions to a marvelous degree. But the real motive power lay deeper than these superficial palliatives, and was embodied in the affectionate and intelligent zeal of the men.

"These were the pioneers of the electric light," said Mr. Edison, "and to their faithful labors is due the widespread introduction of the system."

From this tried and trusty phalanx five men were selected and entrusted with the important charge of the incandescent lamp, in connection with the French Electrical Exposition of 1883. The concentrated and sustained energy which they displayed in the promotion of Edison's interests was such as to attract universal comment. The Gaul, whose field of action lies rather in the achievement of daring and short-lived deeds, and whose excitable temperament lends itself but seldom to feats involving sustained endurance, looked with open-eyed wonder on this band of men, toiling night and day, without adequate food, rest or sleep, in the interests of an employer thousands of miles away. Service of so exacting a nature, and of which Virtue furnished almost the sole reward, had never entered within the observatory scope of the Frenchman, and he was fain to dismiss the subject with a contemptuous shrug, as a fresh proof of foreign eccentricity.

TRANSPORTING THE EXPLORER'S BULLOCK-SKIN BOAT. SEE PAGE 203.

In 1881 Mr. Edison was deprived by death of his wife, the intelligent and sympathetic companion of his early manhood, and the mother of his first three children. His sorrow was deep-seated and genuine, but work, as well

A NATIVE BEAUTY.

as time, is a wonderful panacea for human troubles, and the inventor owed too much to public life to indulge in the luxury of private grief. He was soon ardently engaged in the fruition of his multifarious schemes, many of which demanded a considerable amount of migration. In the development of the machines for generating electrical power Edison established himself at Goerk street, New York city, in the building formerly known as the Etna Iron Works. A chosen band of followers accompanied him, W. S. Andrews, as superintendent of the testing and experimental department—a position which shortly after devolved upon Mr. W. K. L. Dickson, while the other offices were filled by George Grower, H. N. Marvin, Charles Edgar and Nicola Tesla. Mr. Andrews proved himself then, as he has since, one of Edison's most valuable lieutenants, and his executive skill, gently yet forcibly exercised, went far toward smoothing the path of his successor. Mr. Edgar, now manager of the Boston Edison Electric Light Company, lent his efficient aid in the development of the callow enterprise, and replaced

his chief so ably as to admit of many flights on the part of that restless scientist. Mr. Marvin, the inventor of the electric drill, exploited by the Marvin Electric Drill Company, in this found a congenial field for the exercise of his abilities. Nicola Tesla, that effulgent star of the scientific heavens, even then gave strong evidence of the genius that has made him one of the standard authorities of the day; but like most holders of God's intrinsic gifts, he was unostentatious in the extreme, and ready to assist with counsel or manual help any perplexed member of the craft. Such were the men at Goerk street, and many a delightful symposium comes to remembrance in which these congenial elements took part. Time was not, and surroundings were forgotten, as they listened spellbound to the emanations of Tesla's brilliant intellect, alternately fired with the rapid sketching of his manifold projects, or melted into keenest sympathy by pictures of his Herzogivinian home.

HUNTING FOR FIBRE—YAK FRUIT TREE.

The Goerk street shop was grim of

THE CARPENTERS WHO BOXED THE BAMBOO.

aspect, not over clean, and located in an uninviting portion of the great metropolis, but neither space nor practical appliances were lacking, and the years which antedated the removal of the enterprise to the magnificent establishment at Schenectady, in December, 1886, were years of brilliantly successful, if anxious, thought. Edison's experimental work on the dynamo was tinged with a daring which went far towards neutralizing the monotony of the proceedings. On one occasion a force of men were engaged in testing a new type dynamo, which had been greatly reduced in size, and was giving more light than was anticipated. Mr. Edison was so pleased by this unexpected electrical energy that he started on a series of tests to discover how high the engine could be run without flying into pieces,—not that that trifling contingency would have been an obstacle to investigation. When the capacity of the engine had been reached, the order for more steam was given in the usual classical terms : " Fire up, men, let her go." At first we stood round at a respectful distance from the engine, but as this began to exhibit growing signs of ferocious activity, we became suddenly interested in side expeditions to a large and solid brick building, attached to the shop, where Mr. Edison awaited reports. The climax finally came in the shape of a deafening roar,

which heralded the bursting of the main steam pipe, leading to the engine. Nothing worse occurred, at least nothing resulting in loss of limb or life, but it was a lively experience just the same. However, the demonstration was scientifically complete, from Mr. Edison's standpoint, and what mattered a few collateral damages.

The beds were more original than luxurious, and generally consisted of a table or bench, with galvanometers and resistance boxes for pillows. But revenge was obtained once in a while, upon the author of these miseries. One night, after an exasperating vigil of many hours, one of the boys conceived the brilliant idea of putting the clocks several hours ahead, so as to induce the slumbering chief to quit work a little earlier. On awakening, after one of his cumulative naps, Edison found, to his amazement, that it was 4 A.M. and gave the order to stop for that night. He was puzzled to discover that his watch, usually so reliable, should be a laggard to the tune of six hours, and was still more astonished, on emerging into the streets, to find many of the theatres emptying themselves. Then it was that he realized the nature of the joke perpetrated, and indulged in a hearty and unresentful guffaw.

Curious indeed were the types of humanity which were attracted to Goerk street. One morning Edison sent word to prepare for the coming of Sitting Bull and his tribe, and after an animated scuffle of two hours, everything was ready to receive the distinguished guests. At the appointed time they arrived, sitting in all their war paint and grotesque bedizenment on the top of several omnibuses and carriages. Stolidly they surveyed matters from their elevation. Stolidly they descend-

HUNTING FOR FIBRE—THE HARBOR OF SINGAPORE.

ed and stalked through the establishment, betraying by neither word, sign, nor look their appreciation of the unusual surroundings. Edison's sense of fun was roused by their behavior, and shaped itself into a practical joke, which will doubtless be long remembered in that quarter. He ordered one of the dynamos to be stopped, ran a wire, heavily insulated with cotton, and attached it by both ends to the generating machine. He then stationed the Indians close to the wire, which ran the full length of the main shop, and watched their faces closely, while the metallic thread was getting red hot. No interest was evinced until the burning cotton rose in a cloud, and filled their eyes with the stinging incense, when a loud "hugh" was heard, and much vigorous rubbing of the eyes ensued. Edison got some of the burnt cotton in his eyes, but the success of his experiment consoled him for this trifling casualty.

ONE OF THE NATIVES THAT THE EXPLORER MET.

The introduction of the Edison lamp, with the superior claims made for it by Mr. Edison, gave rise to a tide of abuse, detraction and stinging sarcasm, such as inevitably falls to the lot of all but safe mediocrity. The waves of public feeling rose and fell, scintillating with brilliant predictions, or darkened by clouds of gloomy foreboding. Among the men of the time who entertained pessimistic ideas as to the ultimate success of the incandescent light, was Professor Morton, of Stevens Institute of Technology, who embodied his views in a dismal and scathing lecture, delivered before a large body of the initiate and uninitiate. These adverse criticisms called forth Edison's assertion, that some day when the Edison light had attained its apotheosis, he would erect a statue to this raven of science, inscribed with the words : "This is the man who said the Edison light would never work," framing the statue in the

A NATIVE AT WORK.

perfected effulgence of the new illumination. Among the many poisoned shafts, winged at Edison, was the oft-repeated asservation: "No line of original discovery marks the electric light. Long before the days of this presumptuous claimant, the vexed problem of incandescent electric lighting had received practical solution at the hands of our best scientists." Mr. Edison at no time has ever advanced a claim of original discovery in connection with the electric light, but he does claim, and with undeniable justice, that in his hand the immature and scattered principles of his predecessors were perfected, and welded into one symmetrical whole. In his hands the incandescent electric light was disinterred from the fruitless seclusion of the laboratory, and transferred to the plane of practical utility. From a costly toy, interwoven with intricate mechanical difficulties, and gifted with but a limited period of existence, it has become an all-important factor of public life, embodying the features of evenness, power and inexpensiveness, which were so conspicuously lacking in former systems. Not that we would deny the indispensable basis, afforded by prior investigations, or the undeniable talent and energy, displayed by former scientists,—on the contrary, we are disposed to admit, in a large measure, the self-evident proposition advanced in our question. At the same time it may be maintained, that the very excellence of these methods enhanced the difficulties of Edison's task, and threw into broader relief its superior merits. Any perambulating clodhopper may add to the pebbles in a roadside cairn, but only Titans may pile Ossa upon Pelion.

The first public exhibition of the incandescent electric lamp was given in the winter of 1880, at its birth place, the inventor's laboratory in Menlo Park. Visitors flocked from every portion of the United States, impelled by commercial or scientific interest, and their numbers were so great as to necessitate the introduction of special trains on the Pennsylvania Railroad, between Jersey City and Menlo Park. The plant comprised about 700 lights, which were distributed in the most effective manner throughout the grounds, the streets and the internal arrangements of the Edisonian metropolis. The majority of the conductors were laid underground in much the same manner as gas, and a public demonstration was thus afforded of Mr. Edison's claims in regard to the feasibility of commercial lighting which won

the confidence of the most cautious capitalists, who forthwith besieged the inventor with schemes for the extension of his methods, many of which were eventually carried into operation. The notoriety afforded by the Menlo Park Exhibition had a most stimulating effect on the new company. The stock rose to $3000 a share, although its par value had originally been only $100, and newspapers and visitors competed in the circulation of the new methods.

An amusing scientific dispute, born of the Menlo Park achievements, arose about this time, as to the nature of an extremely brilliant light which appeared in the western heavens overhanging the hamlets of Rahway, Ramapo and Suffern. Suffern boasted of a schoolmaster whose word was law on all disputed points of erudition, and whose faculties had largely been enlisted in following up Edison's experiments with the electric light. He had been one of the interested spectators on the occasion of the Menlo Park illumination, and had returned to his native haunts more impressed than ever with the effulgence of Edison's genius, so that when the mysterious luminary sparkled on the darkling brows of the Ramapo Mountain, and society fell into a dispute as to its nature, he promptly decided it to be an electric light. Edison was just now engaged in experimenting with an electric light and a balloon, at Menlo Park, distant forty miles—so the gaping audience was informed—the object being to ascertain how long that special phase of illumination could be induced to burn in the upper regions of the air. Upon the successful outcome of this test hinged important issues, the system being before the consideration of government in connection with the signal service and coast lighting. To this oracle, the justice, doctor and storekeeper—minor potentates of Suffern—gave their unqualified assent, the only dissenting voice being that of the village postmaster, who referred the new phenomenon to an astral source, and detected a suspicious family resemblance to Venus. He was swept aside, however, by the tide of public opinion, and the new appearance was definitely registered as the product of Edison's brain. Many tributes have been laid at the inventor's feet, but none which could vie with the above in absolute naïveté of admiration.

(*To be continued.*)

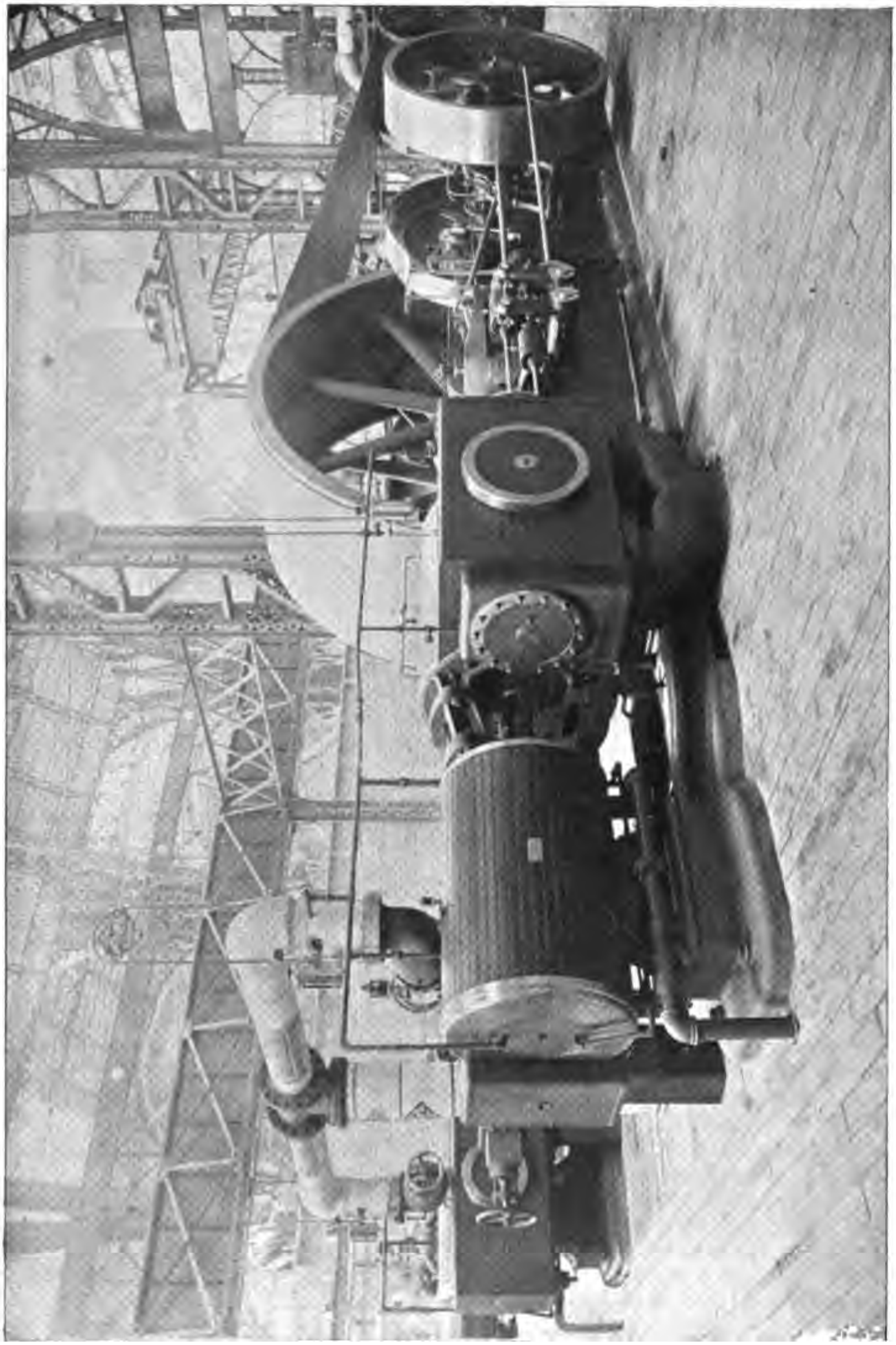
MACHINERY HALL, WORLD'S COLUMBIAN EXPOSITION.

STEAM ENGINES AT THE WORLD'S FAIR.—III.

By Geo. L. Clark.

EVERYONE who has made a tour of the Fair buildings at Chicago, brief though it may have been, has probably found one thing worthy of emphatic condemnation, and that is, the system, or perhaps more truthfully speaking, the lack of system, of ventilation. In none of the buildings is this more uncomfortably apparent than in Machinery Hall where, from the nature of the exhibits, the heat during some of the days is trying indeed, certainly sufficient to interfere materially with the pleasure and profit of sight-seeing. The vast skylight area, with the sun beating down upon it, transforms the buildings into veritable hot houses with no means of egress for the heated air nor ingress for fresh air from without. The skylights unfortunately are set on a slope with the roof, whereas, had they been set vertically, and hung on vertical pivots, with ropes handy to turn their edges to the sun, a fair degree of comfort might have been secured. As it is, the atmosphere is overheated and confined, and in Machinery Hall, at least, the discomfort is much increased by the heat radiated from the large assemblage of engines and almost endless length of steam piping. One of the queer edicts that went forth from those in authority at the Fair was that all engines and all boiler fronts should be of immaculate white, much to the well-founded disapproval and annoyance of those builders who had taken special pains to make their exhibits attractive in appearance by such means as finely-finished jackets, nickel plated trimmings and the like. White paint has, therefore, been freely used, but scarcely with wholly pleasing results. Any one, in fact, might well have foreseen what this white color craze for engine decoration would bring about. Bright and clean as the white-painted engines certainly looked when everything was new, it took but a short time for the paint to blister more or less and peel off, and for oil and grease to further disfigure it, and give the originally brilliant white a rusty, dirt-streaked aspect. Those of the engines which were left as the builders sent them—and there are a few of them—certainly shine by contrast, and present an effective and business-like appearance.

Not a few of the engines shown depart from the ordinary, well-known lines of design, and give the impression that they were built specially for exhibition at the fair. A goodly number of makers, however, show simply their standard types which have been on the market for longer or shorter periods.



DOUBLE TANDEM-COMPOUND ENGINE, BUILT BY MESSRS. MCINTOSH, SEYMOUR & CO., AUBURN, N. Y.

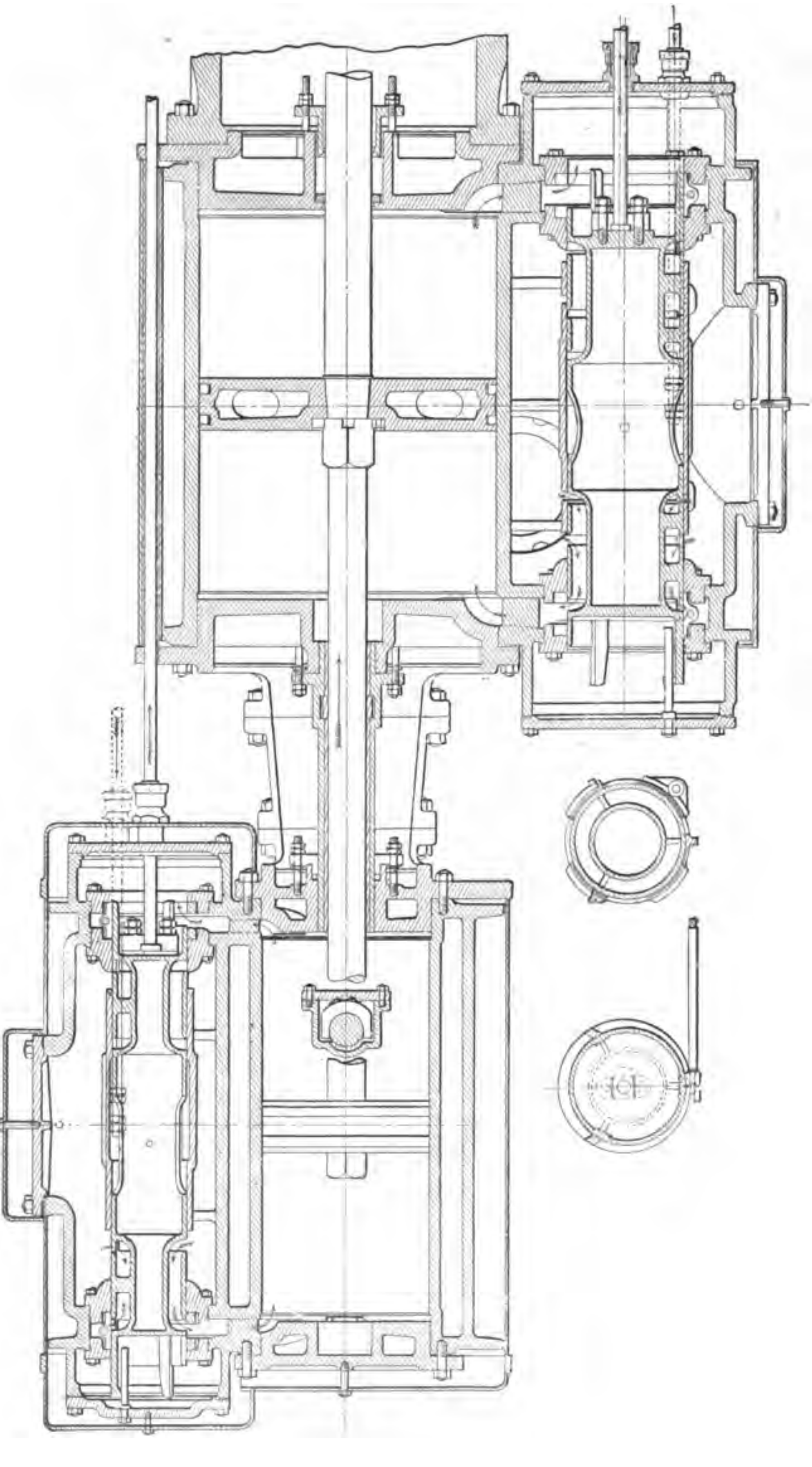
Prominent among the special designs of which several illustrations have already been given in the preceding papers, is a 1200 horse-power, double tandem compound engine, built by Messrs. McIntosh, Seymour & Co., of Auburn, N. Y. The high pressure cylinders of this engine measure eighteen, and the low pressure cylinders, thirty-two inches in diameter, while the stroke amounts to three feet. A speed of 112 revolutions per minute is maintained. The sectional view which is given of one of the pairs of cylinders will help to give a better idea of some of the principal details of the design.

Between the high and low pressure cylinders there is what the builders call their split connecting head and metallic packing sleeve. This sleeve is lined with compressed babbitt metal, and is bored out to exactly fit the piston rod, which runs in it. The self adjusting block, as is shown in the section through the tube, takes up wear, should any occur, from the weight of the rod and pistons. The bearing surface of the piston rod on the packing sleeve is nearly as great as that of the cross-head, and forms a good method of guiding the pistons and supporting their weight, allowing them to be suspended exactly central in the cylinders. The piston rod being steered at two points, that is, the packing tube and the cross-head, at some distance from each other, makes the running of the engine very smooth. The packing sleeve also does away with all stuffing boxes between the two cylinders, and is arranged so that it can be pushed into the high pressure cylinder by loosening up the packing gland. By removing the distance pieces in the split connecting heads, the low pressure cylinder heads can thus be slid away from the low pressure cylinders, and the latter are made easily accessible without disturbing the high pressure cylinders in any way. All the cylinders are provided with relief valves of special design, which can be set to open automatically at any desired pressure, and at the same time can be opened by hand, serving as cylinder cocks.

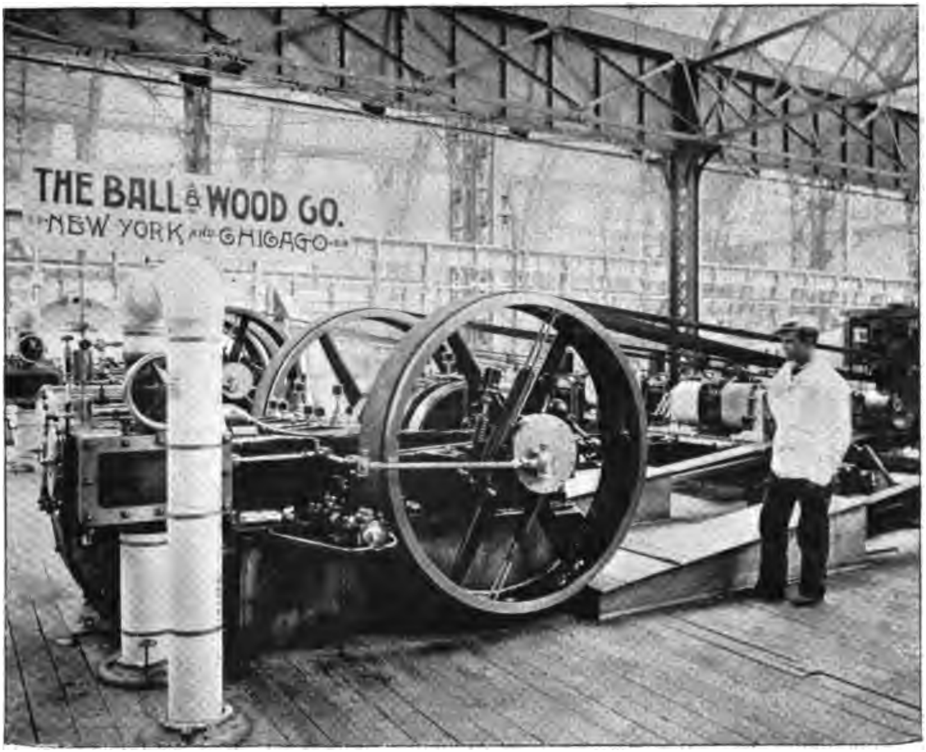
The main valves of the engine are of the piston type, with the two ends extended to meet in the centre, so that when one of them is opened on the steam end, the port connects, not with the steam chest, but with the central space in the valve, ports being cut through from this space to the exterior to connect with the steam chest proper. On the outside of the valves in the steam chests ride simple sleeves which serve as auxiliary cut-off valves, and are directly under the control of the governor, being, thus, automatic in their action. The main valve on each cylinder is driven by a fixed eccentric. The main valve seat consists of a ring, or rather two rings, made in one piece and connected by several bridges across the port-opening which the space between them forms. The seat is crescent shaped, split and adjustable to fit the valve, by the stem which extends to the upper side of the steam chest, where it can be turned by a box wrench. The adjustment can be easily and quickly made.

The governor is very similar to the governor used on the single cylinder engines built by the same firm, except that the eccentric, instead of being moved across the shaft, is simply rotated about it by the action of the governor weights, correspondingly changing the point of cut-off. A plate spring is used in the governor. Both sides of the engine are operated from the same governor through the intervention of a rock shaft which extends across and drives the cut-off valves on the further side.

A specially noteworthy feature of these engines is found in the fact that auxiliary shafts are used to carry the governor and eccentrics, and also the transmission gear wheel driving the condenser. These auxiliary shafts are driven by means of drag links which, in turn, receive their motion from extensions of the main crank pins, the object of the whole arrangement having been to reduce the sizes of the different parts of the valve gear and to correspondingly decrease their friction. The governor, in virtue of this feature of



LONGITUDINAL SECTION OF CYLINDERS OF THE MC INTOSH, SEYMOUR & CO. ENGINE.

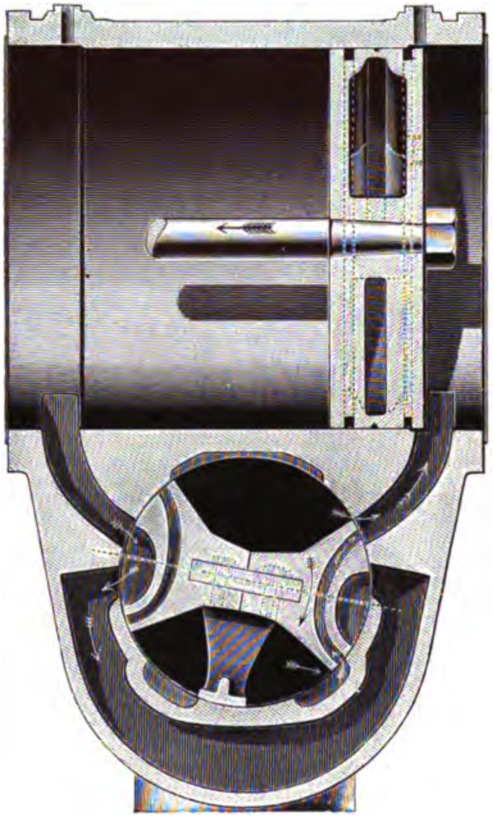


CROSS-COMPOUND ENGINE, BUILT BY THE BALL & WOOD CO., NEW YORK.

the design, also is brought down to a smaller size than usual, and is more sensitive and will act more quickly than if it were mounted on the main shaft. The cut-off valves are, to a certain extent, cylindrical grid-iron valves, as will be understood from the sectional view.

The high pressure cylinders are provided with steam jackets, and the receivers between the cylinders are filled with copper heating coils, presenting a large amount of heating surface, and tending to give perfectly dry steam at the entrance to the low pressure cylinders. The builders argue that the cause of inefficiency of steam jackets on high pressure cylinders, as ordinarily made, is lack of proper circulation through the jackets, and that a very rapid circulation is necessary to render them operative. By the present arrangement the temperature of the steam in the receiver being much lower than that in the coil, a very considerable amount of condensation takes place in the receiver coil, and as this is fed from the high pressure cylinder jacket only, a brisk circulation is insured in the latter. The pipes from the high pressure cylinders to the receivers are also fitted with steam separators to catch any water which may be carried along by the passing steam.

The main shaft of the engine is made of hammered wrought iron, measures fourteen inches in diameter in the main bearings, sixteen inches in diameter between them, and weighs about 33,000 pounds. The main bearings, which are twenty-four inches long, are provided with water jacket shells lined with babbit metal. The lower one in each case is machined on the outside to the shape of a true sphere, and the bed frames are recessed to correspond. In this way a ball and socket bearing is formed for each journal, insuring uniform distribution of pressure over its surface.



SECTIO OF BALL & WOOD LOW PRESSURE CYLINDER AND VALVE CHEST.

which is provided with a gauge glass showing the amount of oil in it. A small eccentric on the drag link shaft above mentioned drives an oil pump, the suction pipe of which is connected with the oil settling chamber, while the delivery pipe feeds the oil to the upper sides of the journals. This oiling device appears to be eminently satisfactory in its operation. The oiling, it

THE BALL & WOOD HIGH PRESSURE VALVE.

will be understood, is continuous and automatic, and the bearings are kept practically flooded.

The engine frames extend out under and support the high pressure cylinders, and the latter are bolted to them, but still are free to move longitudinally to compensate for expansion and contraction of the cylinders

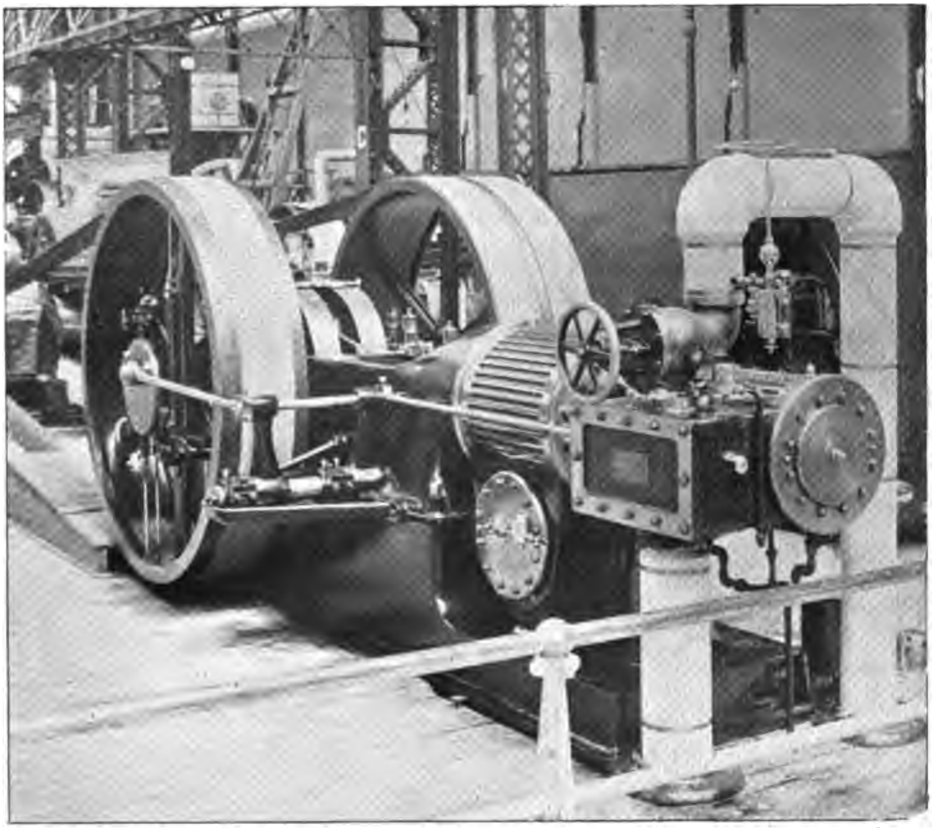
INTERIOR OF BALL & WOOD ENGINE VALVE CHEST.

Through bolts, tightened up after the bearings have been allowed to align themselves properly, fasten the latter securely to the frame. The shells are provided with cheek pieces for taking up wear horizontally, and can be slid around and taken out in a few minutes by jacking up the shaft enough to take the weight off the bearings. The lower cross head guides also are water-jacketted, being cored out for this purpose. They are separate from the frame.

Underneath the bearings, and cast in the frame, is a large oil settling chamber. Bronze rings are placed on the shaft at the end of the journals, which throw all oil fed to the bearings into channels and lead it into this settling chamber, with varying temperatures. The fly-wheel is not the least interesting part of the engine, being cast in four pieces,

with two sets of arms ; in fact, it is practically made up of two wheels, placed side by side upon the shaft and bolted together. Each of these four pieces is cast separately, planed up, and bolted together by reamed bolts, the splits in the rim of each half being placed opposite each other. The wheel is prevented from bursting by twenty-four three-inch bolts at the rim, and sixteen two and five-eighth inch bolts at the hub. This, of course, does not include bolts holding the hub and rim together laterally. The rims are provided with broad internal flanges in the centre and at the edge for stiffening the wheel and preventing oil from getting on the belts. The wheel is sixteen feet in diameter and seventy-eight inches broad, and weighs 62,000 pounds. The total weight of the engine is 250,000 pounds.

The Ball & Wood Company, of New York, show, altogether, five engines, the exhibit being made up of two of their simple automatic engines, with sixteen by sixteen-inch cylinders, rated at 150 horse-power each; two tandem-compound engines with extended base, cylinders measuring thirteen by twenty by sixteen inches, and also rated at 150 horse-power each ; and one cross-compound engine of 200 horse-power, with cylinders measuring fourteen by twenty-two by twelve inches. The engines are connected by belts to sixteen Brush dynamos which furnish current for arc

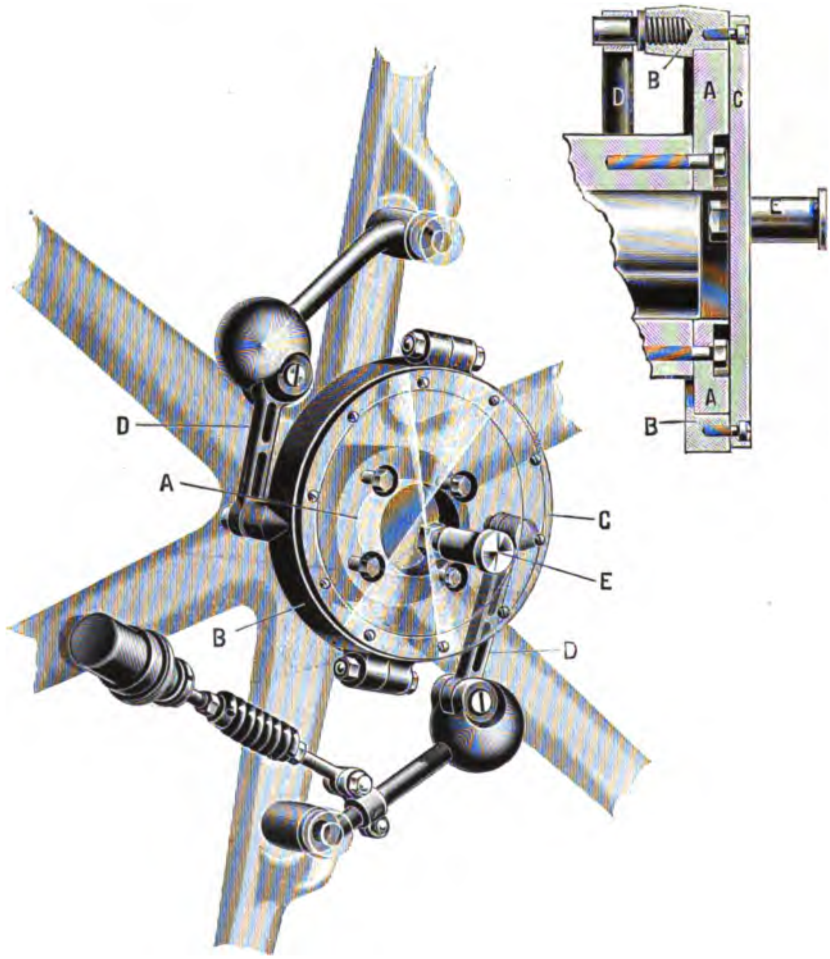


TANDEM-COMPOUND ENGINE, BUILT BY THE BALL & WOOD CO., NEW YORK.

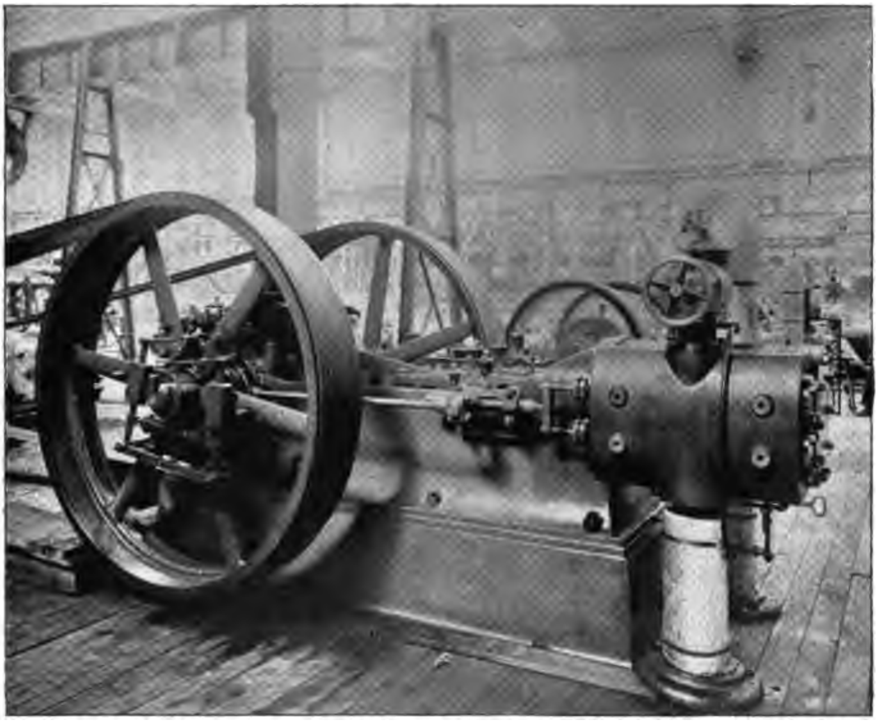
lights used in the Exposition grounds. General and detail views of the cross-compound and of one of the tandem-compound engines are given in this number.

A feature of these engines which at once attracts attention is the arrangement of the low pressure valves. It will be observed that the valve chest on the low pressure cylinder is cylindrical in shape, and is placed transversely to the axis of the cylinder, and directly underneath it. In the sectional view, small arrows in the passages indicate the direction of the flow of the steam, and larger arrows in the moving parts show the direction of their motion. The valve chest is made very large in diameter, so that the steam ports are short and direct.

Two double-ported valves, with arc-shaped facer fitting the bore of the valve chest, are placed opposite each other and are mounted loosely on a central valve stem which drives them both and allows both to be held in contact with their facer by steam pressure. Steam is admitted from the valve chest over the edge on the end of the valve, and also through the port in the valve, thus

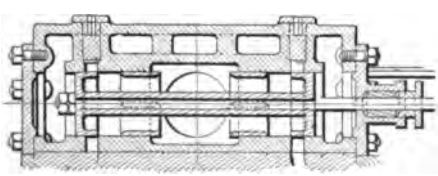


DETAIL OF GOVERNOR OF BALL & WOOD ENGINE.



HIGH SPEED AUTOMATIC ENGINE, BUILT BY THE NEW YORK SAFETY STEAM POWER CO., NEW YORK

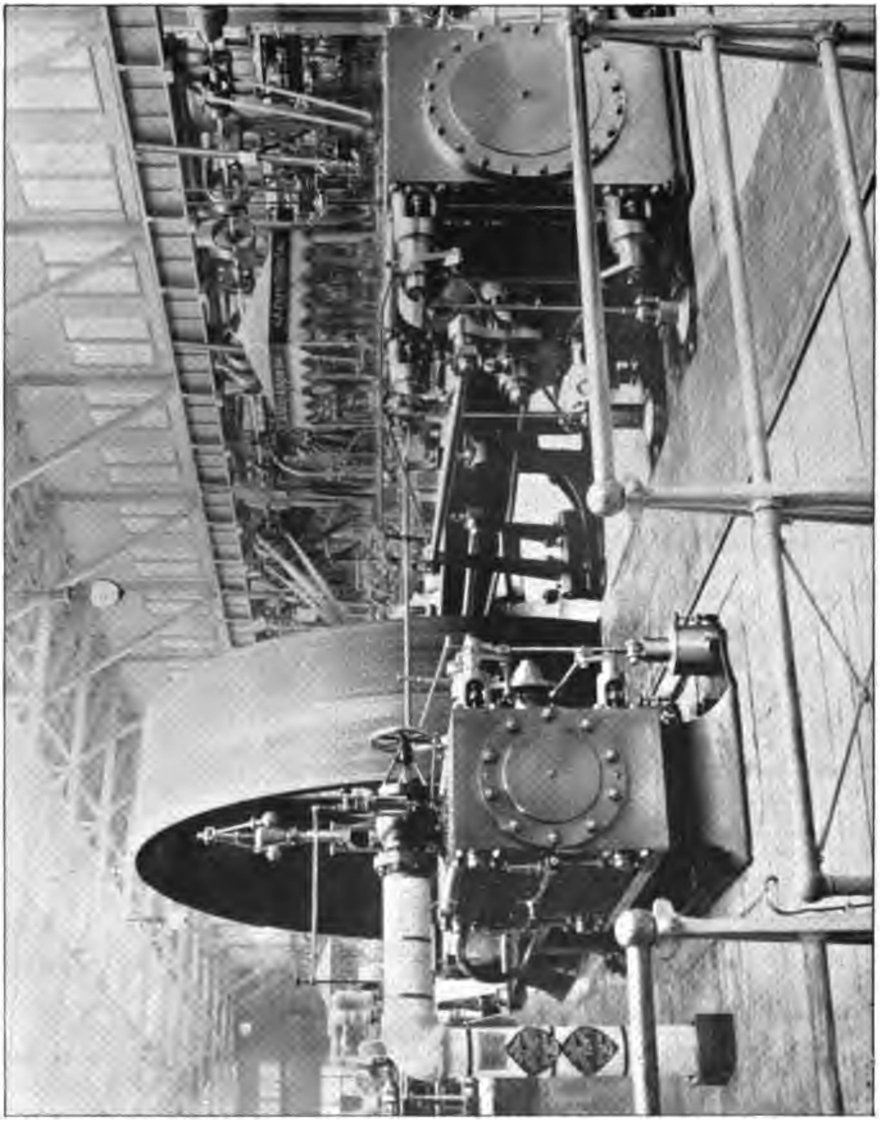
giving a very rapid and wide opening. At the same time the exhaust from the other end of cylinder, has a very direct passage to the condenser. The valve stem carries on its outer end a rock arm which receives motion from a simple



SECTION OF ONE OF THE NEW YORK SAFETY ENGINE VALVES.

crank pin on the outside of the balance wheel, thus dispensing with an eccentric and having all the parts easily accessible. The whole valve mechanism is made very simple by this arrangement, the number of parts is small, and the valves, as already intimated, give a wide and quick opening and follow up their wear with steam pressure. The clearance also is small owing to the short and direct ports, which, moreover, are so located, as will be understood from the illustration, that they readily drain away water accumulations from the cylinder and reduce thechances of accident from such accumulations.

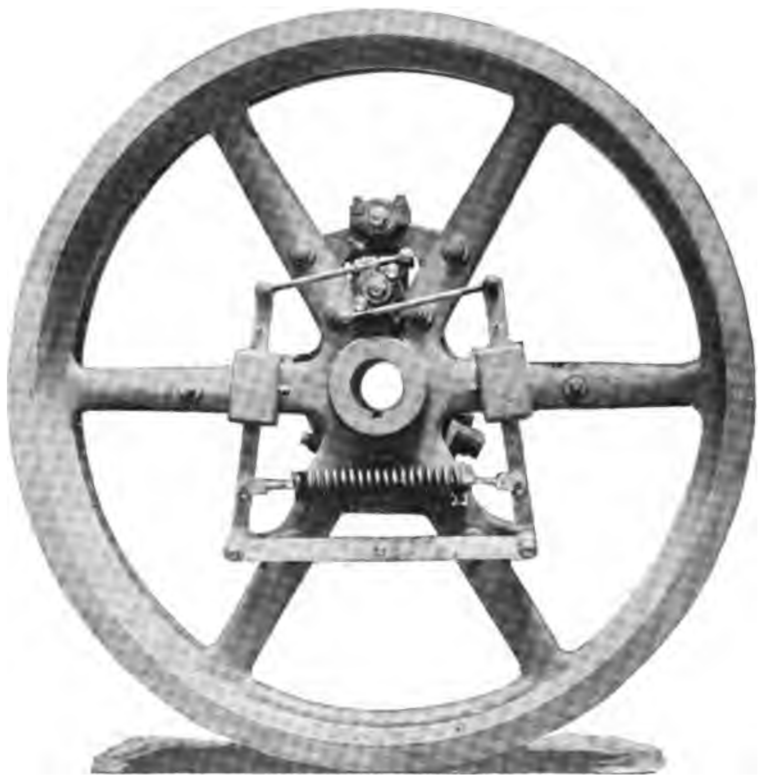
The valve on the high-pressure cylinder is substantially the same as that used in the Ball engine, described in the preceding paper. An additional view of it is given here, together with a view of the inside of the high-pressure valve chest. It may not be amiss to repeat that the valve is made in two parts, with telescopic sleeves connecting them and allowing the valve faces, which are opposite each other, to be held against their respective seats by steam pressure. The steam, it must be remembered, is admitted to the



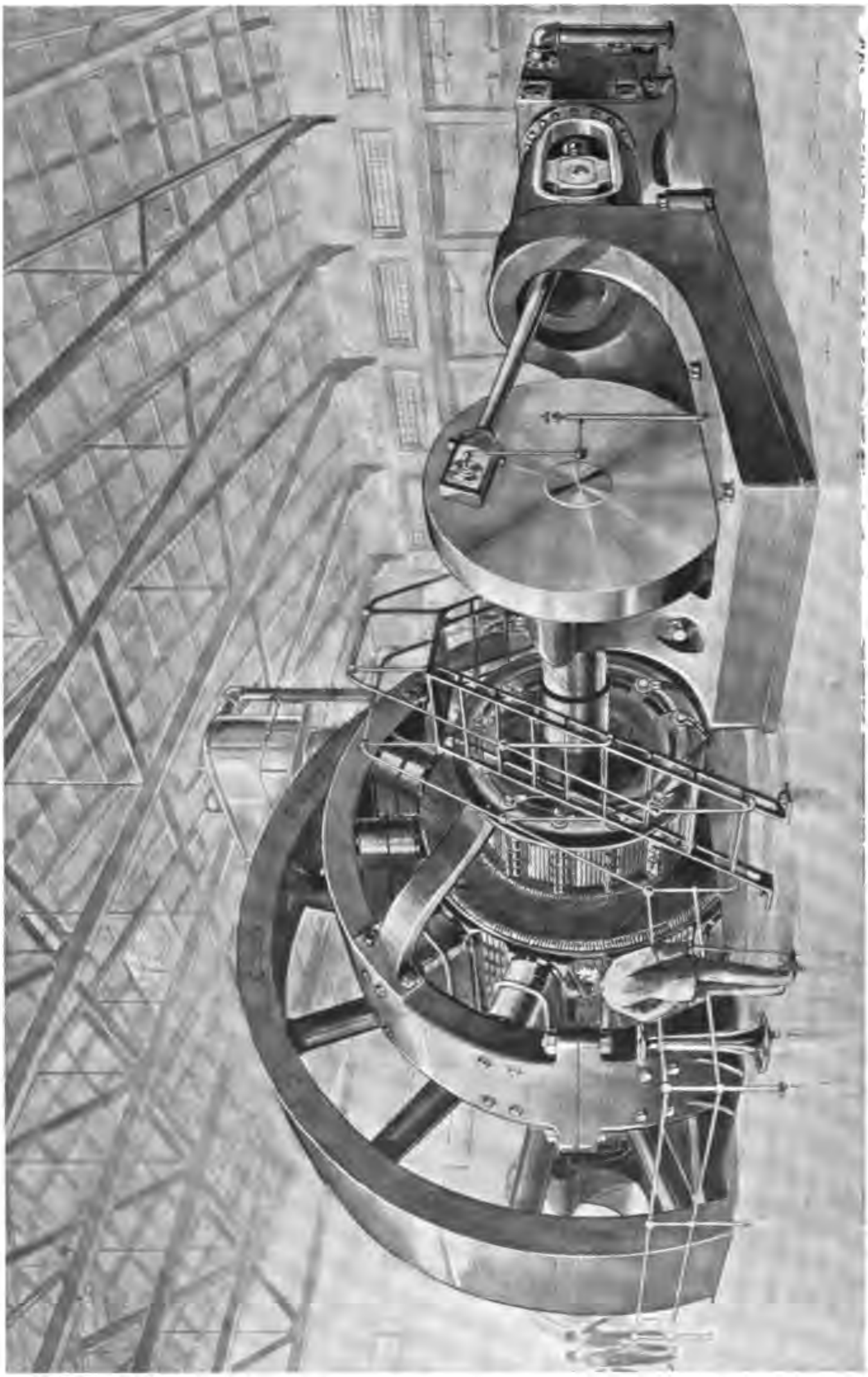
CORLISS COMPOUND CONDENSING ENGINE, BUILT BY THE BASS FOUNDRY AND MACHINE WORKS, FORT WAYNE IND.

interior of sleeves and thence through the ports into the cylinder, from which it is exhausted past the ends of the valve into the steam chest and out through the exhaust pipe at the bottom. The diameter of the sleeves, of course, determines the amount of pressure with which part of the valve is held to its seat. A judicious choice insures just enough pressure for good contact and not enough to cause undue fiction and wear.

The main features of the governor of the engine are well shown in the annexed engravings. The hub of the governor wheel is shown with the eccentric *A* bolted to its outer end, and forming practically part of it. The eccentric strap *B* is made in halves, and is held in place on the eccentric by a flange on one side and a plate, *C*, on the other. The governor weights are connected by links, *D*, to studs in the sides of the eccentric strap, so that the strap and the plate *C* are turned slightly around the eccentric by the radial movement of the weights. Motion for the valve is taken from the crank pin, *E*. Since the radial movements of the weights turn the plate *C* around its centre, which is eccentric to the shaft, the pin *E* naturally is moved through the arc of a circle whose centre is the centre of the plate. The curved path of the crank pin *E* is made to give almost a constant lead to the valve until a very early cut-off is reached, when the lead rapidly disappears. It will be seen that only two moving surfaces are interposed between the shaft and the road which actuates the valve. Of these the crank pin *E* is practically



GOVERNOR OF NEW YORK SAFETY STEAM POWER CO. ENGINE.



THE E. P. ALLIS CO'S CORLISS ENGINE, COUPLED TO GENERAL ELECTRIC GENERATOR, FOR OPERATING THE INTRAMURAL RAILWAY WITHIN THE FAIR GROUNDS.

the only wearing surface, as it is the only one constantly in motion relatively to the surfaces with which it is in contact. The other, the eccentric strap, moves on the eccentric only when the weights change their position.

A further contribution to the high-speed, automatic engine exhibit is made by the New York Safety Steam Power Company, of New York, one of whose centre-crank engines, slightly different in point of valve detail from the company's standard type, is shown driving some electrical machinery. In this engine, as in the one just described, a relatively small degree of clearance is secured by having the steam ports close to the ends of the cylinder. Unlike the standard type engine, which has only one main valve, the engine on exhibition has two main valves, or, perhaps more correctly speaking, the main valve is made up of two parts, the detail view shown being a longitudinal section through one of them. Each of the parts has its separate valve stem, and the two stems, in turn, are connected and driven by one eccentric rod as shown in the general view.

The valves are of the balanced piston type and are controlled with corresponding ease by the governor. The paths of the live and exhaust steam in getting to and from the cylinder need no special explanation; the sectional view tells itn own story.

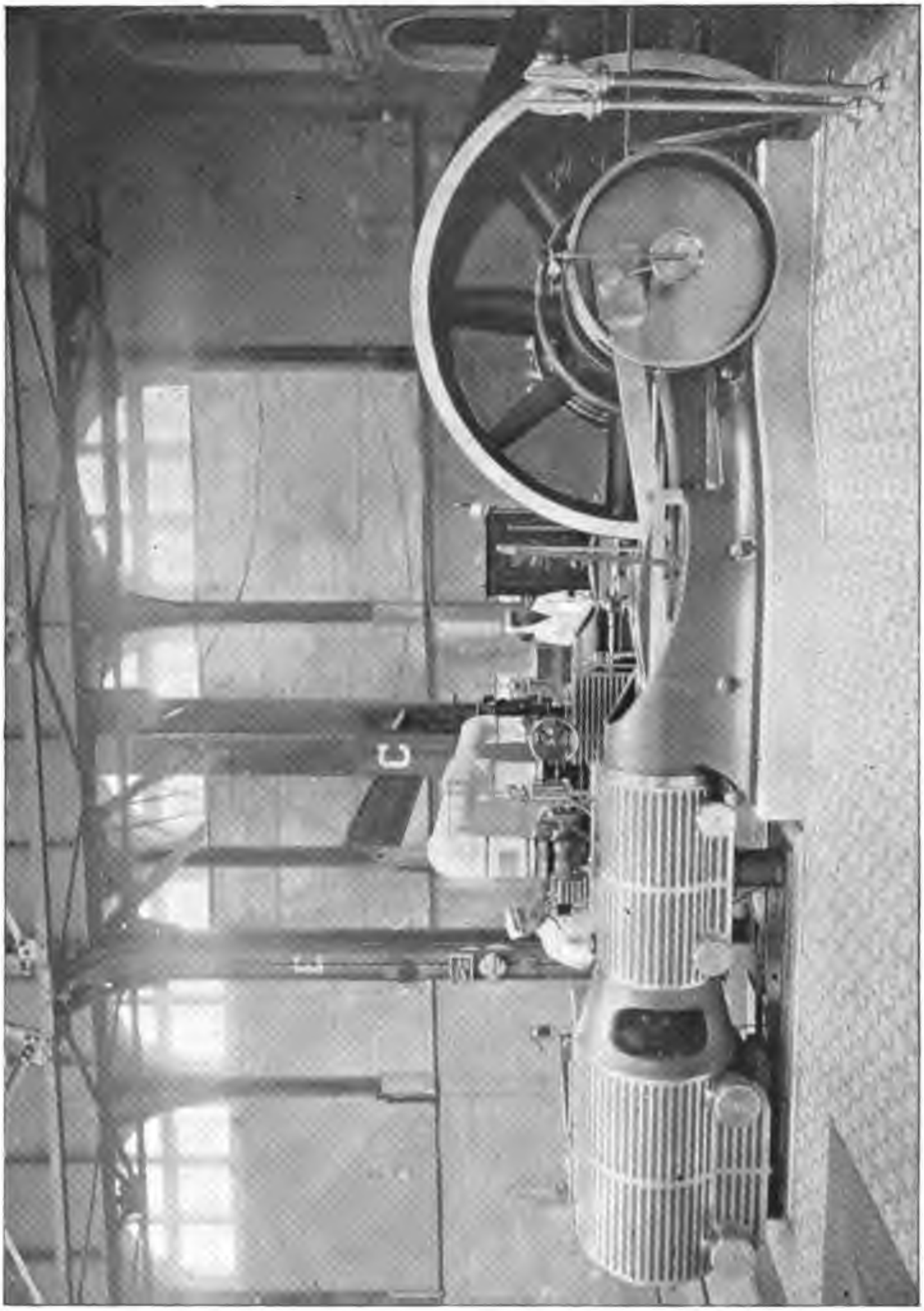
The main valve stem which works the two valves through the intervention of the two subsidiary stems connected, as already stated, by a crosspiece, passes through an accurately squared crosshead, which slides in a long squared guide, firmly fixed to the engine frame. This crosshead has a steel pin projecting from one side, which takes the eccentric rod; thus but one pin-journal is employed between the valve stem and the eccentric.

In the governor two eccentrics are used. The main eccentric has a slotted arm which projects radially and is hung upon a pin, or shaft, having a bearing in the governor frame, as shown above. The secondary eccentric shaft, located below, carries two arms, which are connected by links to the levers supporting the governor weights; the other end of the shaft is a small eccentric, which fits into a block which has vertical play between guides affixed to the arm of the main eccentric.

The action of the governor is as follows: When the engine is at rest, or is moving at a speed so slow that the tension of the spring overcomes the centrifugal force of the weights, the centre of the main eccentric is at its extreme point distant from the centre of the shaft, and the valve has its greatest travel, the steam being allowed to follow the piston to nearly seven-eighths of the stroke. As the engine increases in speed, and the centrifugal force of the weights overcomes the tension of the spring, the cam is slightly turned to its block, and throws the centre of the main eccentric nearer and nearer to the centre line of the crank, until the desired speed is attained. When the limit of its throw is reached, the travel of the valve is only equal to the lap and lead of the valve. The leverage being great, and the eccentricity of the cam being very slight, but little force is necessary to partly rotate the cam and move the main eccentric.

On the other hand, the resistance of the cam to any opposite force is so great that, when connected, the main eccentric cannot be shifted, except by reason of the movement of the weights and lever connections of the cam shaft. The swinging of the eccentric causes the lead to increase as the travel of the valve shortens. The speed of the engine may be varied either by change in the tension of the one spring employed, or by change in the position of the weights, or both. The direction in which an engine shall run is also within the control of the engineer, and the changes necessary to reverse can be quickly made. The governing mechanicism is an independent part of the governor wheel, complete in itself, and can be applied without much trouble to any other wheel, should it become necessary or desirable to make a change in size.

The engine frame is cast in one

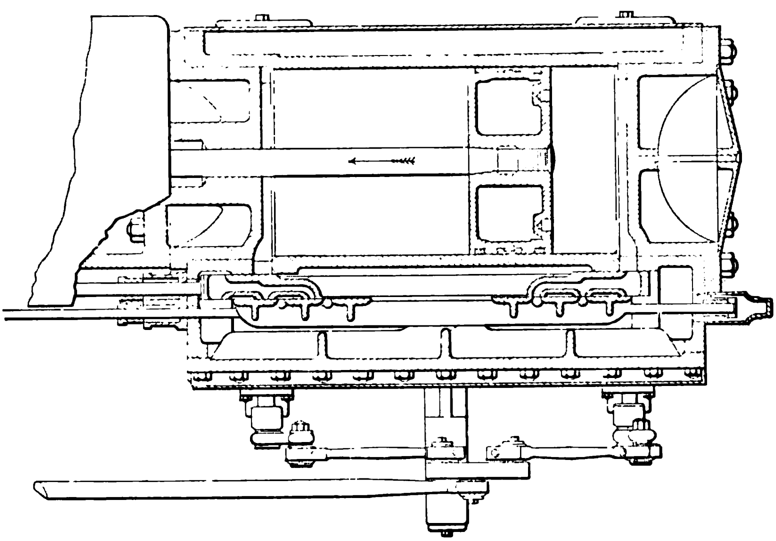


DOUBLE TANDEM COMPOUND FOUR-VALVE ENGINE, BUILT BY MESSRS. RUSSELL & CO., MASSILLON, O.

piece, embracing all the bearings of the engine, and a drip pan extends around the bottom edge to collect oil and water drippings and carry them to a common point of discharge. The engine shown at the Fair has a 15½ x 16-inch cylinder, runs at a speed of 250 revolutions per minute, and is rated at 150 horse-power.

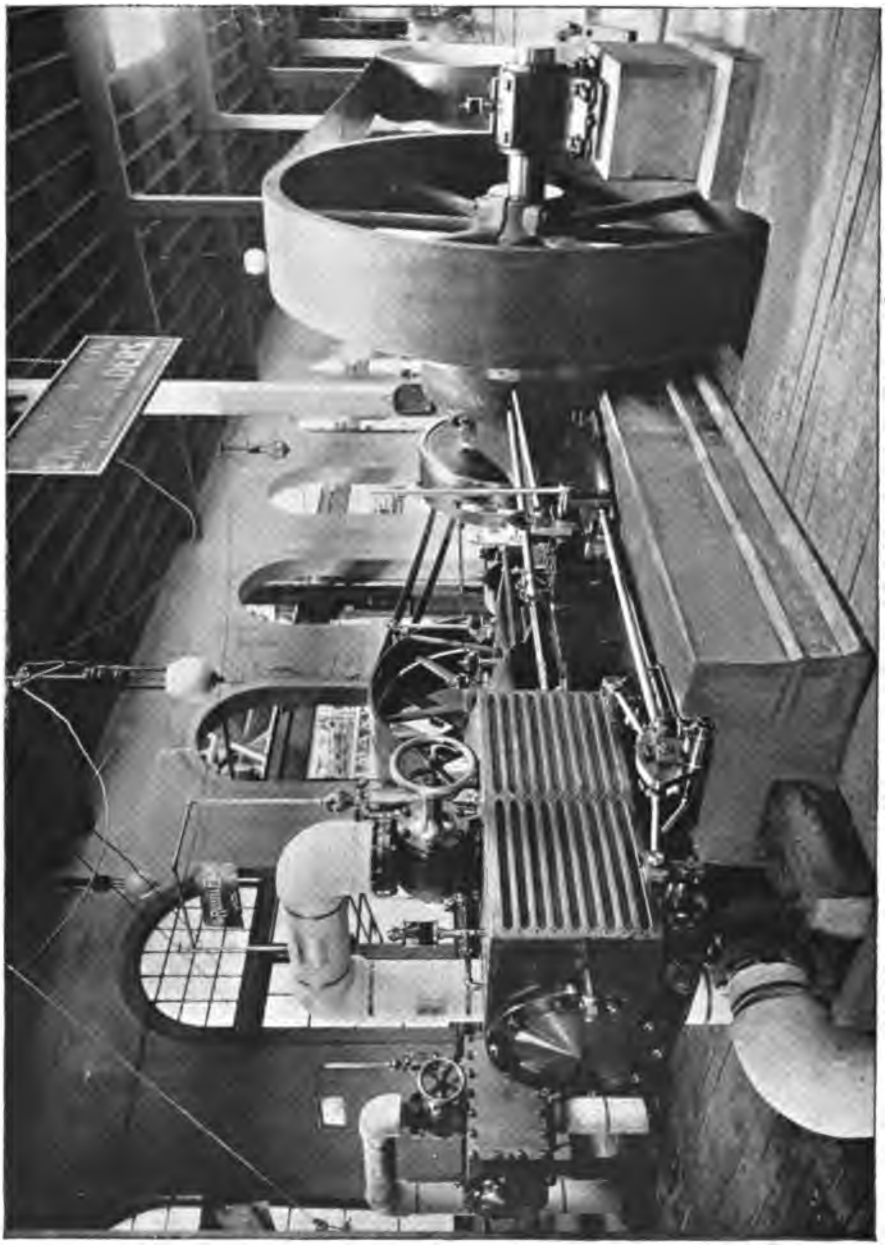
The exhibit of the Bass Foundry and Machine Works, of Fort Wayne, Ind., consists of one of their regular cross-compound Corliss condensing engines, rated at 300 horse-power. The engine, which is driving dynamos for incandescent lighting, is worked in connection with a Wheeler surface condenser, and has sixteen and thirty inch cylinders, with a stroke of forty-two inches. The driving pulley is sixteen feet in diameter and has a forty-two inch face. The cut-off in both the high and the low pressure cylinder is under the control of the governor. The engraving which is given of the engine shows all its principal features quite clearly, and makes a more detailed description unnecessary.

One of the features of the transportation facilities at the Fair is the Intramural Railway, which, as is generally known, is operated electrically. The current for the line is supplied by a gigantic 2000 horse-power multipolar railway generator, built by the General Electric Company, of New York, and driven by a correspondingly imposing cross-compound condensing engine of the Reynolds-Corliss type, made by the E. P. Allis Company, of Milwaukee, Wis. The engine and generator, while not, strictly speaking, one of the regular exhibits, form an interesting addition to the Machinery Hall display, and reference to them in connection with the present account of the World's Fair steam engines is, therefore, not inappropriate. They are set up in the Intramural Railway power house, and enjoy the distinction of being the largest combination of this kind in the world.



SECTION OF CYLINDER OF FOUR-VALVE RUSSELL ENGINE.

The generator itself is a twelve-pole compound wound machine. Each pole is first wound in usual spool fashion and then securely bolted to the massive iron field constructed of two enormous semi-circles of cast-steel, bolted together the lower of which is provided with supporting feet. This field is fifteen



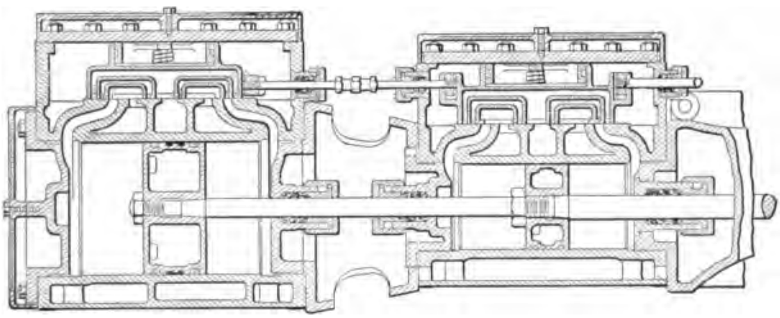
FOUR-VALVE AUTOMATIC HIGH SPEED ENGINE, BUILT BY MESSRS. RUSSELL & CO., MASSILLON, O.

feet in diameter, and weighs considerably over 80,000 pounds. The breadth is just three feet. The armature is of the iron clad, ventilating type; that is to say, each of its separate windings is buried in its individual mica-lined slot in the exterior surface of the laminated body. The armature is wound on a cast iron spider weighing over fifteen tons, which is rigidly keyed to the ponderous shaft of the immense engine. The diameter of the armature is ten and a half feet; its breadth, over three feet, and its weight, over thirty-five tons. The shaft to which it is keyed is two feet in diameter, and weighs fifty-five tons. The commutator is seven feet six inches in diameter. The temperature of the armature, under full load, will not rise over 40 C. above the average temperature of a room.

The brush holders, of which there are twelve sets, corresponding to the twelve poles, are of a novel design. They are carried on an outside brush holder yoke, supported on one side of the field magnet frame, and are moved into position conveniently by means of a special shifting gear, operated by a hand wheel. The brushes are easily accessible from a staircase passing over the revolving shaft. The generator is entirely independent of the engine, with the exception of the armature which is fitted to the shaft.

The efficiency of this enormous creation is claimed to be ninety-six per cent. In its mechanical construction special provision was made for allowing a wide fluctuation of load and speed without affecting the efficiency of the machine. The number of revolutions per minute at which it runs is seventy-five. It is wound for 600 volts.

The engine driving this mammoth generator, and to which brief reference has already been made above, has a high-pressure cylinder thirty-two inches in diameter, and a low-pressure cylinder sixty-two inches in diameter, the stroke being sixty inches. Both engine and generator run at a speed of seventy-five revolutions per minute. The weight of shaft and its load is about 160 tons. The fly-wheel is twenty-five feet diameter and weighs eighty-two tons. A thirty-two by sixteen-inch Reynolds vertical air pump and condenser, fitted with a Corliss valve gear, works in connection with the engine, which is specially heavy in design and so arranged that either side is capable of handling 2,000 horse-power in case of necessity.



SECTION OF CYLINDERS OF SINGLE-VALVE TANDEM-COMPOUND RUSSELL ENGINE.

The exhibit of Messrs. Russell & Company, of Massillon, Ohio, comprises six automatic engines. One of these is a double tandem-compound, four-valve engine, measuring 15x24x24 inches, and running at a speed of 125 revolutions per minute. It has a balance wheel measuring 120 by 60 inches, and weighing 36,000 pounds, and the total shipping weight of the two engines complete amounts to 89,172 pounds. The engines will develop

600 horse-power, with a claimed water consumption, accounted for by the indicator, of 14½ pounds per horse-power per hour running non-condensing. The admission and cut-off valves are triple-ported, balanced slide valves, balancing being effected by admitting steam between the valve faces, leaving narrow strips or bridges for the valves to ride on. Actual contact of surfaces is prevented, and the valves are really carried between layers of steam, making their movement a very easy one. The cut-off valves slide on the backs of the main valves, and are operated by a separate eccentric, which is connected to the governor so as to cut-off proportionately to the load. The extreme range of cut-off extends from 0 to ¾ stroke. The cut-off eccentric, as usual in governing arrangements of this kind, fits loosely on the engine shaft and is connected with the weight arms in such a manner that it is moved around the engine shaft, either forward or backward, as the weights change their position, thereby cutting the steam off earlier or later in the stroke as the governor, or more properly the weights, adjust themselves to the load. When the cut-off eccentric is rotated forward, that is around the shaft in the direction the engine runs, the steam is cut off earlier in the stroke; when the eccentric is rotated backward the steam is cut oft later in the stroke.

The exhaust valves are cylindrical in shape and are operated through wrist-plates by the same eccentric that works the main steam valves, but their connection to the wrist-plates is such as to insure a "dwell" at the time of steam admission, and a correspondingly rapid motion at the time of release. This makes the maximum travel of the exhaust valves occur at a time when the pressure upon them is very small and insures smooth working. The whole valve gear, it will be understood, is designed so that the cut-off valves of both high and low-pressure cylinders are under the control of the governor.

A second compound engine, shown by Messrs. Russell & Co., is of their single valve type, with 13x20½x20-inch cylinders, and running at a speed of 180 turns per minute. This engine will develop 200 horse-power on a claimed consumption, as accounted for by the indicator, of eighteen pounds ot steam per horse-power per hour when running condensing, and twenty-two pounds when running non-condensing. The main features of this engine are well shown in the sectional view of the cylinders and valve chests. In addition to this engine there are two simple, 17 x 24-inch, four-valve automatic engines, running at 150 turns per minute, and essentially the same, so far as valve details are concerned, as the four-valve, double-compound engine already described. Each of these engines will develop 200 horse-power, with claimed water consumption, as in the preceding case, of eighteen and twenty-two pounds per horse-power per hour when running condensing and non-condensing respectively.

A fifth engine, exhibited by the same builders, is a simple 13 x 18-inch single valve automatic engine, running at 235 turns per minute and designed for an economic load of 100 horse-power, the water consumption claimed for this engine being twenty-two pounds per horse-power per hour when condensing and twenty-six pounds when non-condensing. The valve of this engine takes steam from underneath and is held to its seat by enough steam being admitted into the chest to accomplish this purpose without overloading it. The steam is admitted to the cylinders through "carry-over" double ports, and the exhaust is accomplished through a "D" passage.

(To be continued.)

LIFE AND WORK OF GUSTAV ADOLPH HIRN, 1815-1890.

By Bryan Donkin, Jun. Mem. Inst. C. E.

FEW men of science have had a calmer and less eventful career than Gustav Adolph Hirn. Born near Colmar in 1815, the whole of his long life was spent within a circle of a few miles of his birth place. His pecuniary circumstances were easy, and he did not need to leave his native town to seek fame or fortune. Neither had any attractions for him. The one object of his life was the advancement of science, and to it he devoted himself with the steadfast zeal and disinterestedness which were a part of his nature. The different stages in his mental development are marked by the titles of the various books he published, and he desired no other monument, nor could he have had one more fitting. It is his contributions to experimental science, and his studies of the laws of heat and thermodynamics, which constitute his chief claim to honor. If he cannot be ranked with the great discoverers of the world he followed them closely, and by his original and patient researches greatly furthered the cause of science. By the force of his keen intellect, desire for knowledge, and love of truth he was led on from one field of investigation to another, till the ground he covered was truly amazing. But work was to him always its own reward. That he achieved fame and celebrity, and became the founder of a great school of experimental physics, and one of the foremost scientific men of the century was of small consequence to him compared with the object of all his labors, the progress of science.

Gustav Adolph Hirn was the youngest of five brothers and sisters, and was born on the 21st August, 1815, at Logelbach, a small village about a mile and a half from the town of Colmar in Alsace. Logelbach properly speaking consists only of a large cotton spinning and dyeing establishment, and the houses of the work people, owners and foremen. In the middle of the last century the grandfather of Hirn, Jean Michel Haussmann, a chemist of repute, founded here one of the first cotton factories in the district. The firm became known as Haussmann, Jordan, Hirn & Co., and Haussmann's son-in-law, Jean Hirn, the father of the subject of this memoir, was a partner. Jean Hirn was a painter of fruit and flowers, and would have distinguished himself in art, had he devoted his mind to it, instead of commerce. For one of his pictures he received a gold medal, and another is in the Gallery of the Louvre at Paris. In estimating his son's character and work, this double inherited leaning to science and to art must not be overlooked. Gustav Hirn was always an artist as well as a man of science. From his maternal grandfather came the ruling passion of his life, his love of abstract and experimental research, and his mechanical dexterity. The power of grasping a subject, of scientific intuition and lofty generalization he traced to the artistic instincts of his father.

Nor did his art influence merely the scientific side of his character. He was an excellent musician, and published a treatise on "Acoustics; or, Harmony in Music," and others on the mathematical theory of the metronome. In early life he was a first-rate violin player, but for some reason, partly perhaps his failing eyesight, he laid

down his bow. For twenty years before his death he gave up playing, though he always enjoyed listening to the music of others. Had he chosen art as his profession he would certainly have attained eminence. He was an excellent judge of music, fastidious in his taste, and giving the highest place in his regard to Beethoven. He was able to direct the performance of difficult music, and even of Wagner's compositions with the ease and finish of a professional conductor, and he possessed the rare faculty of reading fluently musical scores, and thus obtaining a knowledge of their contents.

Gustav Hirn was self-taught, and never went to a school or university. One of his earliest recollections was the establishment of the great spinning mill, set up at Logelbach between 1822 and 1824. It was worked by an English steam engine, one of the first Watt engines sent to the continent, and the interest with which the child watched the erection of the great machine may be imagined. When he was only five years old his eldest brother died from the effects of an accident at the Strasburg Lyceum, where he had been sent to school. This calamity made his parents determine to educate the four younger children at home, and to this cause Hirn attributes the defective mental training he received. Another and probably the chief reason was his delicate health as a child, a delicacy which he never completely outgrew. His great soul inhabited a feeble body, and the results he achieved are the more marvelous when we consider his constitutional difficulties, and especially his bad sight. Speaking on this subject he says that his life should encourage others, and teach the lesson that "suffering and sorrow are often powerful auxiliaries to develop the capacities of a man, and make him produce whatever seems to belong to his vocation." He learned with his brother and sisters under a master at home, a professor of the college at Colmar, and began his chemical and physical studies under M. Kaeppelin, for whom he always retained a grateful remembrance. But in all the higher branches of study he was entirely self-taught. It is astonishing to find that with his great mathematical capacity he had no master to initiate him into this difficult study. Certainly the knowledge he gained for himself was more laboriously, but also more thoroughly acquired.

For a man of his original genius it was an advantage, which possibly decided his future scientific work, that he did not follow any definite course of study. His mind was never forced into a conventional mould, nor made to undergo the harassing drudgery of examinations. Thus, when he began his scientific studies he was untrammeled by theory. Having never submitted to the dictum of any master or professor he entered the arena of science, so to speak, as a free lance. Instead of taking his stand upon the work of others, he carved out a line for himself, and following Bacon's method, he reasoned from facts instead of from theoretical deductions. He first made his experiments, and then proceeded to draw logical conclusions from them.

Hirn was not only a scientific man, but an accomplished scholar, and so earnest a student that the difficulties caused by the want of the usual early training were soon surmounted. He knew German, English, Latin and Italian ; his musical acquirements have already been mentioned. He was all his life a great and judicious reader, and what he read he never forgot. He was blessed with a splendid memory, and one who knew him intimately in his later years declared that he never perceived the least diminution in his extraordinary retentive faculty. Hence he was able to grasp, appreciate and preserve the connection between the most varied branches of knowledge, and the originality of his genius was strikingly shown in the way in which he made them all subordinate to the main philosophical principles he spent his life in establishing.

At the Logelbach cotton factory his father's artistic talents had been turned to account to devise the patterns and colors of the materials woven, and as

soon as his son was of fit age he associated him in the work. Young Hirn, when nineteen years old, was admitted to the chemical laboratory, where the colors for dyeing were prepared. He was at once initiated into the drudgery of a toilsome daily life. He was obliged to rise early, and to work hard all day at the manipulation of the dyeing materials, a difficult and unhealthy occupation. The nature of his employment made him devote his attention at first to the study of chemistry, for which the laboratory of the cotton factory was placed at his disposal. Possibly the weak health he had to contend with through life was aggravated by the unwholesome work in which, while still so young, he was obliged to engage.

In 1842 the dyeing establishment and chemical laboratory were given up, and the work of the mill confined to the spinning and weaving of cotton cloth. This event formed an important epoch in the life of the young mechanician, and perhaps determined the whole future course of his life. He was now associated with the engineering department of the factory, and all the engines driving the mill were placed under his control. For the next thirty-five years he acted as chief engineer to the firm, and instead of devoting his attention to chemistry, he applied it to steam machinery. He had already begun to study mechanical science, and had published two small papers "On the Mechanical Theory of Ventilators," in 1845, and "On the Gauging of Water Courses and Tumbling Bays," 1846. Both the papers were read before the Société Industrielle de Mulhouse, a society to which he remained attached all his life by the closest bonds. It was by this society that the famous papers were published on the steam engine superheated steam, and steam jackets,

HIRN'S RESIDENCE AT COLMAR.

which laid the foundation of Hirn's great fame as a scientific worker and discoverer. The benefits conferred by the connection between him and the society were mutual. While he was still young and unknown the society encouraged his maiden efforts, and held out the helping hand for lack of which many a man of genius has failed in his efforts to communicate his knowledge. It was the society which published his epoch-making work on friction, when other associations had rejected it because it militated too strongly against the then received opinions. On the other hand Hirn's glory was reflected on the Société de Mulhouse, and helped to raise its reputation.

Hirn's papers on the steam engine, and his subsequent scientific work, were the fruit of the careful study which with his characteristic zeal and earnestness he bestowed upon the engines under his care. He had at his disposal in the mill three turbines, a double-cylinder condensing engine of 112 horse-power, and a single cylinder engine of 110 horse-power. He immediately perceived and began to avail himself of the unique advantages the charge of these engines offered for studying the phenomena of heat. Here he was able to make experiments continuously, extending over a long period of time, and to vary the conditions under which the engines worked, in every possible way. This method of procedure was in accordance with the habit of his mind to obtain facts first and theories afterward, and from a long series of trials he deduced results which startled the scientific world. He had his engines under personal, closest supervision, and often rose in the middle of the night to see if they were working satisfactorily. The house in which he spent the greater part of his life was a large building with square façade, exactly opposite the chief entrance to the mill. Not a stone's throw distant was the smaller house where he was born, and in one or other of these two houses he lived till he was sixty-five years old. A few steps across the road brought him to the engine-house, a small building attached to the main factory. Here were the two engines on which he made all his experiments ; he himself devised and applied the apparatus required for testing them under various conditions. On one occasion when his fame was already diffused through the scientific world, Verdet visited the celebrated engineer and philosopher. While walking through the Logelbach mill with him he requested Hirn to show him at the same time his laboratory and the apparatus and instruments with which he had obtained such wonderful results. "It is my laboratory through which I am taking you," was Hirn's answer.

About the year 1850 Hirn began those celebrated experiments on the steam engine that were destined to make him famous. After working at them continuously for nearly thirty years his tests were brought to an abrupt conclusion by the break-down of the historic engine at Logelbach on the anniversary of his birth, August 21st, 1878. He had been showing it to a friend and disciple, Professor Dwelshauvers-Déry of Liège, and his son, and had just quitted the engine house when the accident happened. The main shaft broke, the beam was damaged, and the piston rod injured. With characteristic unselfishness Hirn did not give a thought to the danger he had run himself, nor to the loss of his engine, but hurried off to his friends to ascertain if they were safe. The damage was fortunately soon repaired.

The fame which Hirn acquired as co-discoverer with Joule and Mayer, of the law of the mechanical equivalent of heat, and founder of a new experimental method of accounting for the heat given to an engine, soon attracted a band of followers to his side. Almost unconsciously and against his wish, for he was always desirous of carrying out his work in modest silence, he became the founder of a school of experimental science, which has since acquired fame as the Alsatian school. Among the first and most devoted of his disciples was Hallauer, with whom he was united in the closest friendship. Hallauer was the inventor of the differential air ther-

mometer, and always zealously co-operated with Hirn in all his labors. It was he who, in conjunction with Leloutre and Grossetête, was appointed by the Société Industrielle de Mulhouse to verify Hirn's startling assertion that the economy of steam in an engine cylinder is greatly affected by the action of the walls and by the use of a steam jacket. He also first drew attention by his experiments to Hirn's methods of study. Hirn told a mutual friend that Hallauer had never caused him but one sorrow, his death in 1884. On that occasion Hirn wrote a touching memoir of his friend, whose loss he never ceased to deplore.

Other followers of Hirn and disciples of the Alsatian school were M. M. Grossetête, Leloutre, Meunier and Keller and Professor Dwelshauvers-Déry of Belgium. All were ardent fellow-workers with their great master, following the lines indicated by him to arrive at a true knowledge, apart from theory, of the complicated phenomena taking place in an engine cylinder. As a scientific worker Hirn was not, however, without his keen critics. During the latter part of his life he came into conflict with the great German physicist, Professor Zeuner. The battle waged between them was humorously described by one of Hirn's followers, G. Schmidt, of Prague, as "the war of iron versus water." Zeuner maintained that the phenomena exhibited in the cylinder of a steam engine, and especially the loss of heat during expansion, must be chiefly ascribed to the presence of water in the cylinder. Hirn attributed it to the influence of the walls. The discussion, which was hotly carried out, had the excellent effect of drawing attention to the work of Hirn, and the results obtained by the Alsatian school.

During the eventful years from 1842 to 1880, when the discoveries of Hirn and others were revolutionizing previous scientific theories of the steam engine and the laws of heat, the great philosopher led a calm and simple life at the Logelbach mill. In 1858 he married Mademoiselle Lucie Mausbeudel, of Mulhouse, and although they had no children the union proved singularly happy. Madame Hirn was a woman of superior ability, and she devoted all her talents to the service of her husband, whom she greatly assisted in his work. Hirn's eyesight had always been feeble, and as early as 1842, before he had commenced his scientific labors, he lost the sight of one eye. It would have been impossible for him to carry out his researches without the zealous co-operation of his wife, whose unremitting care of him, and modest but assiduous aid were continued to the last day of his life. His habits were always simple and regular. Summer and winter he rose at five; at six he was at his desk and worked till eight. The next few hours were occupied in visiting and inspecting the engines under his charge and in attending the daily committee at which the affairs of the mill were settled. He then returned to work and dictated his business letters and the enormous correspondence he maintained with scientific men all over the world. After an early dinner and a second inspection of the engines he devoted a short time to seeing his friends in town; work was resumed in the evening, and he always retired to bed at ten. He was a bad sleeper, and many of his finest works were composed in his mind during the silence of the night; he used to say that questions which had appeared impossible to solve during the day became clear to him at night, and his splendid memory enabled him to retain whatever he had thought out and to write it down in the morning just as he had conceived it. His method of work was similar to that of other great men blessed with a perfect memory and the invaluable power of assimilating the thoughts of others. The extraordinary breadth of his mind made him able to grasp a subject in all its details at once; he worked rapidly, seldom corrected what he had once written down, and never recast his original text. His secretarv, M. Schwoerer, says of him: "His greatest works were conceived at one stroke; they are the development of a clear,

dominant idea, which scarcely underwent any modification in its execution. He needed neither rough copy nor preliminary notes. When the whole work was clearly impressed on his mind he began to write it out, at first in his characteristic round hand, in his later years he used a typewriter."

Hirn was spared one trouble which frequently falls to the lot of men of science. He had no pecuniary hardships to encounter. Although never rich, he always enjoyed a modest competence. He was not called upon to undergo that struggle with poverty which often hampers and sometimes frustrates the efforts of those who carry out unremunerative scientific researches. The comparatively easy circumstances of his life would have tempted many men to idleness; with him they proved an additional incentive to work. But Hirn was too much absorbed in his scientific and philosophical labors to be in the ordinary sense of the term a good man of business. After his father's death the cotton factory at Logelbach was carried on by him in conjunction with his brother Ferdinand, himself a distinguished engineer and the inventor of rope transmission. On the death of Ferdinand Hirn in 1880 the Logelbach business passed into other hands, and Gustav Hirn retired to his house at Colmar, where he lived till his death. He was now a man of sixty-five, in the decline of life, and his remaining years he consecrated to the abstract studies in which he took ever increasing interest; to art, especially to music, and to the society of a small circle of intimate friends. He occupied himself much with meteorological and astronomical studies, which had always had a fascination for him. His friendship with the great astronomer Leverrier stimulated his ardor, but he had never yet been able to devote sufficient attention to these researches. For many years previously he had, with his brother Ferdinard, carried out meteorological researches at Logelbach, as far as it was possible to do so under the circumstances. The nature of the beautiful country round Colmar, situated between the mountains of the Vosges and the Black Forest, made it a peculiarly favorable place for this branch of study. With the help of the Institut de France he succeeded in erecting an observatory in his house at Colmar, provided with instruments suitable for making meteorological researches. He also established stations at other points in the departments of the Upper Rhine and the Vosges, and from 1881 to 1886 he published various papers upon the subject.

From these practical questions he proceeded to much more profound philosophical studies, and in 1888 he produced his last book, "Constitution de l'Espace Céleste," held by many judges to be his greatest work. The circumstances of the publication were pathetic. Hirn had long been in bad health, and his doctors at last deemed it imperatively necessary to perform an operation. His great work was on the point of completion, and the struggle between his earnest desire to finish it, and the physicians' insistance on the operation, was intense. By a great effort he contrived to put them off till the manuscript was done, and as soon as it was in the hands of the printers he submitted to the operation, which was at first successful. Difficulties, however arose, and he never entirely recovered. He had intended to visit the Paris Exhibition of 1889, but was unable to carry out the project. It was while in this precarious state of health that he was suddenly prostrated in January, 1890, by an attack of influenza, and on the 14th, only a few months after the death of his great rival in the discovery of the mechanical equivalent of heat, James Prescott Joule, Hirn's noble and distinguished career was brought to a close.

Shortly before his death a number of his friends subscribed to present him with a medal in token of their esteem. Fearing, with his delicate health, that some difficulty might arise from the tardiness of the engraver and frustrate the plan of thus doing him honor, a copy was provisionally made and placed

in his hands only a few weeks before his death. The completion of the medal itself was announced by the engraver on the 12th of January, when Hirn was already struck with his mortal illness. It was presented as a mournful consolation to his widow.

Unlike some men of science Hirn was able to reap the reward of his labors, and his merits met with full recognition before his death. During the latter part of his life honors were showered upon him. He was made a corresponding member of the Institut de France, associate of most of the learned societies of Europe, a chevalier of the Légion d' Honneur, and was decorated by the Emperor of Brazil and the King of Belgium. But his most enduring title to honor is the place he acquired among scientific men, the progress achieved by his efforts, and the place he won in the foremost rank of the discoverers and pioneers of science in the present century. The writer of the present memoir was honored with his friendship for many years, and had the privilege of knowing him personally and visiting him in his home at Colmar.

Since his death a local committee has been formed at Colmar and a subscription raised to erect a statue to his memory in one of the squares of the town.

SAFETY DEVICES ON RAILROAD CARS.*

By Gen. Horace Porter.

EVER since the introduction of railways in this country, speed, comfort and safety in travel have been the three salient merits advertised by passenger agents. Since the first trains were put on, speed has quadrupled, comfort has become luxury, and safety, while it has not yet been able to avoid all sources of danger, has fully kept pace with the progress of other improvements.

Much difficulty was experienced for many years from the imperfect methods employed in coupling cars. The ordinary means consisted of coupling pins inserted into links attached to the ends of the cars. There was a great deal of "slack," the jerking of the train was in consequence very objectionable, and the distance between the platforms of the cars made the crossing from one car to another exceedingly dangerous. In case of collisions one platform was likely to rise above that of the next car, and "telescoping" was of frequent occurrence. These difficulties were overcome by devices for more securely and conveniently coupling the cars.

The Miller coupler and buffer was patented in 1863 and obviated many ot the discomforts and dangers arising from the old methods of coupling. This was followed by the Janney coupler and other devices.

The improved means of framing and strengthening cars, required by increasing speed, did not make decided progress until sleeping cars were introduced. The first type of car known as the "Pullman car" was completed in 1864, and the introduction in this car of what is known as the "Pullman upper berth," proved to be a very valuable device in protecting it against being crushed in case of becoming derailed and rolling down an embankment. Experience proved this car to be very many times stronger than ordinary passenger coaches in offering resistance to accidents arising from the causes mentioned. As the sleeping car had to carry greater weight than other cars, the framing of the car had to be made stronger than in ordinary pas-

* From a paper read before the Railway Commerce Congress at the World's Columbian Exposition.

senger coaches, and it was found by experience that in collisions these cars were much less likely to be crushed. Particular attention was thus directed to strengthening the bodies of all cars. The "Pullman end safety device" is one of the latest inventions that have been introduced into the framing of passenger coaches for the purpose of conferring additional strength. It is attached to and forms part of the end frame of a car. The end sill is re-enforced by a broad horizontal plate of steel, to which is riveted a heavy steel angle extending across the whole width of the car. A similar angle is attached to the corners of the floor frame by steel knees, and extending upward in the line of the corner posts, is bent over and across the top beam forming a continuous steel frame around the whole end of the car, so that in case of collisions the colliding engine or car is prevented from crushing into the end and splitting the car open. In fact, the bending of the steel frame produced by a collision tends to draw the floor, sides and roof together rather than to force them apart.

One of the most serious dangers to which passengers and employees were exposed was in passing from one car to another while the train was in motion. The introduction of the improved couplers and buffers brought the platforms closer together and did something toward obviating the difficulty; but in rounding sharp curves at high rates of speed, or during violent wind storms, there were many cases in which persons were thrown from the train. As early as 1852 devices were invented which provided for diaphragms of canvas to connect adjoining cars and form a partly protected passageway between them. These were first applied to cars on the Naugatuck Railroad in Connecticut in 1851, but were very crude and were abandoned after a trial of about four years.

At a later date when dining, smoking and library cars were added to the limited express trains there became an absolute necessity for the construction of some safe passageway between cars, as passengers were then obliged to pass from one part of the train to another. In 1886 George M. Pullman set to work to devise a practical system for constructing a continuous train, and at the same time to provide for sufficient flexibility in the connecting passageways to allow for the motion consequent upon the rounding of curves. His efforts resulted in what is now known as the "Vestibuled Train." The invention was patented in 1887, and introduced a safety appliance more valuable than any yet devised for protection in case of collision.

John Birkinbine

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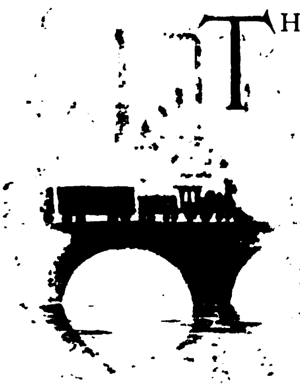
FROM MINE TO FURNACE.

By John Birkinbine, Past Pres. Am. Inst. M. E.

Second Paper.



THE present exploited iron ore deposits of the United States, with incidental reference to some future supplies, may be summarized as follows:

Magnetites occur in Maine, Vermont, New Hampshire and Rhode Island, and the most northerly deposits at present worked in quantity are in the Lake Champlain region of New York. The Chateaugay, Port Henry and Crown Point mines, the best known of these, lie from 1200 to 2000 feet above the lake, and from seven to thirty miles westward. Some magnetites have, however, been found close to Lake Champlain, and others are on the western slope of the Adirondack mountain range. A few of these ores are of the Bessemer grade, and it is believed that more can be made so by crushing the ore and separating the apatite (phosphate of lime) from the iron crystals. Concentration and separation is now carried on to a limited extent, and the use of fine ore in the blast furnace is causing no serious trouble. Considerable magnetic ore sand is found along the coasts of Washington, Oregon, California and Long Island Sound; some of this has been separated by magnetic machines, and it has been claimed that the sub-aqueous deposit from whence these sands emanate affect ship's compasses; in fact, Mr. Edison attributed the loss of the steamer Oregon to such magnetic disturbances.

The Lake Champlain district produces about 500,000 tons per annum, and up to date is credited with having yielded 17,500,000 gross tons of ore, which has been smelted in blast furnaces or reduced by the direct process in bloomary fires. An area of one-half square mile, west of Port Henry, New York, has, it is claimed, produced 4,500,000 gross tons of ore.

Some deposits of magnetite in northern New York, which indicate rich ore in quantity, carry so much titanium as to seriously interfere with their smelting in the present state of our knowledge of ore concentration and blast furnace practice, but this may, like other drawbacks, be overcome in the future.

Magnetites occur again in southeastern New York, in Putnam and Orange counties, within fifty miles of New York City; of those in the former county, the Tilly Foster mine is prominent, with an annual output of from 45,000 tons to 75,000.

Tracing the magnetites from south-

ern New York into northern New Jersey, we find numerous mines in that State producing in the aggregate about 500,000 gross tons per annum, and having in their history added about 18,000,000 gross tons to our ore supply. Many of these ores are high in sulphur and require roasting. In northern New Jersey "franklinite" occurs; an ore containing zinc, manganese and iron which, after it has been roasted, to remove the zinc, as zinc oxide, is smelted in small furnaces to produce "spiegeleisen." Occasionally large crystals of franklinite (with faces of five inches) are found. The Lake Champlain region has been worked since 1804, and the New Jersey magnetic mines have been producers for a century and a half.

Following the ranges of hills into Pennsylvania, the magnetic iron ores occur along the South Mountain, the prominent deposits in this State being at Boyertown, along French creek, at Cornwall, and at Dillsburg. The Cornwall ore hills are practically on elevated ground, and are worked above the water level. The deposit is unique, consisting of a mass of magnetic ore, confined by trap walls forming three hills, and is mined as cheaply as any ore of similar grade in the country. The ore, while sufficiently low in phosphorus for Bessemer steel purposes, carries, on an average, two per cent. of sulphur, which is partially removed by roasting in kilns with waste coal or with gas. The Cornwall ore hills have been worked for over 150 years, and the aggregate output to date exceeds 12,000,000 gross tons, of which 684,714 gross tons were mined in 1892.

The general topographical and geological structure continuing through Maryland, Virginia, North Carolina, South Carolina, Georgia, Alabama and Tennessee, magnetites are found in these States, the largest developments being in North Carolina, at the Cranberry mines in the western and a titaniferous deposit in the central portion of the State.

It was in North Carolina that the first discovery of iron ores in this country was made three centuries ago, in 1585, but the first iron ore shipped from America came from Virginia in 1608.

Ores exist in the western part of South Carolina, and a century ago smelting of these was introduced in that State, but for more than thirty years there has been no iron made there.

This general group of ores just mentioned comprises practically all the magnetites exploited east of the Rocky Mountains, except occasional deposits in the north peninsula of Michigan, in Texas and in Missouri; in these cases the magnetites occur with specular red hematites.

With the exception of Cornwall and one or two other deposits, the magnetites are mined underground, a depth of from 300 to 1200 feet having been obtained in some of the workings of the Lake Champlain, the New Jersey, the Michigan and the Pennsylvania mines. But few magnetites are free from sulphur, phosphorus, copper or titanium.

The most important operations in mining red hematites are in the Lake Superior district, but to indicate the geographical distribution of this class of ores we may first trace them from northern New York, where a considerable industry has been maintained in mining specular ores, into central New York, where the fossil ores known as "Clinton fossils" are wrought. These latter occur again in Pennsylvania, near Bloomsburg, and extend through the central part of the State, supplying stock to numerous blast furnaces; then through Maryland, Virginia and West Virginia into eastern Kentucky and Tennessee, being recognized in the latter State as "dyestone ores," and showing great development in northern Alabama and Georgia. These ores being the basis of supply for the Birmingham, Alabama, furnaces are there known as "Red Mountain" ore.

A peculiar and apparently isolated deposit of Clinton fossil ore exists at Iron Ridge, about fifty miles north of Milwaukee, Wis.; here the ore soon after mining breaks into grains which, from their shape, size and color, have

OPEN PITS OF THE LAKE SUPERIOR IRON COMPANY AT ISHPEMING, MICH.

given to it the name of "flaxseed ore." The Iron Ridge ore carries such proportions of phosphorus, lime and silica as to invite attention to it for use in producing steel by the basic process, and is mined at low cost.

The Lake Superior red hematites are of the hard and soft varieties, the Marquette district of Michigan and the Vermilion district of Minnesota showing the former, and the Menominee and Gogebic districts of Michigan and Wisconsin and the Mesabi range in Minnesota exhibiting chiefly the softer varieties, although soft ores may occur among the harder and *vice versa*.

The noted deposits at Iron Mountain and Pilot Knob, Mo., are speculars, with some magnetites, and in the central part of that State excellent soft, red hematites abound. Ores of this class are also found in Wyoming, Colorado, Arkansas and Texas; while many of the Bessemer ores of the United States are red hematites, such ores low enough in phosphorus for this process are the exception rather than the rule. The purest of these ores command the highest market rates, being shipped, in some cases, fully 1500 miles by water and rail. The Chicago, Cleveland, Pittsburgh, Wheeling and adjacent blast furnaces depend principally upon the red hematites of the Lake Superior district, and large shipments are made to Troy, N. Y., and into eastern Pennsylvania.

One of the recognized conditions of an iron ore suitable for the manufacture of Bessemer pig iron is that it shall not contain over one part of phosphorus to 1000 of iron, but there are cases where ores have been condemned because of an excess of phosphorus, or chemists have been blamed for imperfect analyses where neither the ore nor the analyst were at fault; but the fuel used in smelting the ore in the blast furnace or in melting the iron in a cupola was credited with low phosphorus when it carried a liberal amount; in fact, where low phosphorus is required it is as important to analyze the fuel as the ores or iron for this component.

The brown hematite ores are liberally distributed and are mined in most of the States. The earlier iron industry of the country was sustained principally from the bog variety along the sea coast, but as the settlements extended westward the use of these lean ores was abandoned.

The Salisbury region, embracing portions of western Massachusetts and Connecticut and of eastern New York, has a reputation for pig iron for special purposes produced from brown hematites. These ores also abound in the Lehigh, East Penn, Cumberland and other Pennsylvania valleys, passing then into Maryland, through the Shenandoah, New River and Cripple Creek valleys of Virginia into North Carolina, Tennessee, Kentucky and Alabama, forming in the latter the principal support of the charcoal iron producing industry. To the brown hematites we owe much of the prominence Pennsylvania has won as an iron centre and from them our foundry irons, car-wheel metal, boiler plate and other specialties have been largely prepared. A widely distributed deposit of brown hematite occurs in northern Texas and Louisiana, and outcrops of what are apparently hematites along the Mississippi and Missouri and their tributaries in Mississippi, Tennessee, Missouri, Iowa, etc., are probably weathered carbonates.

Ores of this class are also obtained in Maine, in Rhode Island, on Staten Island, in Delaware, Maryland, Florida, Wisconsin, Michigan, Missouri, Colorado, Utah, Idaho, Montana, Oregon, Washington and other States.

TOP OF IRON MOUNTAIN, MISSOURI.

The brown hematite often occurs in connection with the red hematite. As far as has been exploited, the richer ores of this class are in the Salisbury district of New England, in southwest Virginia, in middle Tennessee and Kentucky, in northern Georgia and Alabama, and in Michigan and Wisconsin, Oregon and Washington. Some other deposits, but slightly developed, however, offer favorable indications as to

quality. The carbonate iron ores are generally esteemed as the least reliable of all varieties; they have been the main dependence of the Baltimore iron industry, and occur between Baltimore and Washington as kidneys in clay. But the quantity is insufficient to maintain a large industry, and the blast furnaces at Baltimore and vicinity are now sustained principally by foreign ores, Cuba supplying the major portion of these. Carbonate iron ores or their derivatives were the instigating cause of the establishment of our western Pennsylvania blast furnaces, as at Johnstown and in the Monongahela and Shenango valleys. Ohio has few ores that are not carbonates, and to these ores the large developments of the Mahoning Valley, the reputation of the Hanging Rock region and the sudden rise into prominence and nearly as sudden decline of the Hocking region is to be credited.

When using this variety of ore, it is generally roasted to drive off the carbonic acid, and other ores are often similarly treated to eliminate the sulphur they contain.

In the production of puddled and rolled iron, the resultant cinder which carries off silica, phosphorus, etc., contains from fifty to sixty or more per cent. iron, and this otherwise waste material is utilized in the manufacture of pig iron by mixing it with natural ores. Owing to existing prejudice its use is seldom referred to as meritorious, and yet there are probably not six mines in the country which contribute so much toward the manufacture of pig iron as this slag or cinder. In some portions of Europe, mill cinder is roasted before it is charged into the blast furnaces.

To a limited extent the residuum from iron pyrites (Fe S), after the sulphuric acid is extracted, is used for the production of iron; this is commercially known as "purple ore," or "blue billy," and is employed in Great Britain more than in this county; a small amount of copper slags have also been so used.

It is not presumed that in this sketch all of the iron ore deposits are referred to, nor is it possible to even enumerate the prominent features of the more important ones in this article.

As mined and supplied to our blast furnaces, the various classes of ores yield about as follows:

Magnetites	from 45 to 70 per cent. iron.	Average 56 per cent.
Specular and fossil ores (red hematites)	" 35 to 68 " "	" 57 "
Brown hematites	" 35 to 55 " "	" 42 "
Carbonates, raw	" 25 to 40 " "	" 32 "
Mill cinder		" 58 "
Foreign ores		" 57 "

The carbonates are widely distributed but at the present time they do not form an important factor in our iron production. They can be traced through New York, Pennsylvania, Ohio, West Virginia, Virginia, Kentucky and Tennessee, into Alabama and Mississippi, and are found in Arkansas, Missouri, Iowa, etc.

The black band variety is used to a limited extent only, and the cheerful outlook which encouraged a large investment of home and British capital to secure in this country similar results to those obtained from these ores in Scotland was not verified in practice.

In 1884, the American Iron and Steel Association determined by careful investigation that, eliminating from the calculation the mill cinder used; the ore employed to produce pig iron in the United States averaged 2.03 tons per ton of pig iron made, being less than was required in other countries; Great Britain averaging 2.4 tons; Germany, 2.6 tons; France, 2.6, and Belgium, 2.7 tons in that year. Since that time a larger proportion of richer ores have been employed in America, and now our average consumption is slightly below two tons of ore per ton of pig iron. In 1889 the census returns indicated that the average yield of iron ores in the American blast furnaces was 51.27 per cent.

The most important source of our

ORE DOCK AT MARQUETTE, MICH.

domestic ore supply is the Lake Superior region, the output of the four districts embraced in it being sufficient to produce about sixty per cent. of the pig iron which we make.

In the year 1880, thirty-one and one-half per cent. of the total iron ore product of the country was red hematite; in 1889, it had risen to sixty-two and one-third; in 1890, to sixty-five and two-thirds per cent., falling off slightly in 1891, when the percentage of the total was sixty-four, but rising to seventy-one and a half per cent. in 1892.

The brown hematites constituted twenty-seven per cent. of the total iron ore mined in the United States in 1880, the proportion declining in 1889 to seventeen and one-third per cent., and in 1890 to only sixteen per cent., but advancing in 1891 to nineteen per cent., and in 1892 declining to fifteen and one-fourth per cent. of the total.

Thirty per cent. of the country's iron ore output in 1880 was of the magnetite variety; but in 1889, less than seventeen and one-third per cent.; in 1890, sixteen per cent., in 1891, less than sixteen per cent., and in 1892 twelve per cent. of the total was of this character of iron ore.

The percentage of carbonate ore used shows a constant decline from eleven and one-half per cent. in 1880 to three per cent. in 1889, two and one-third per cent. in 1890, one and one-third per cent. in 1891, and one and one-quarter per cent. of the total product for the country in 1892.

While the above indicates a decline in the proportion of all the ores used except red hematite, a comparison of the outputs for 1880 and 1892 shows a material decrease in quantity in carbonates only; the magnetites and hematites having an augmented production.

Of the total iron ore output Michigan contributed over 7,500,000 tons; Alabama, 2,250,000; Pennsylvania over 1,250,000; Minnesota 1,000,000, and New York nearly 1,000,000 tons; the total of these five States aggregating

13,000,000 tons, or over seventy-nine per cent. of the country's output of domestic ores for 1891. This total will exceed 13,000,000 tons by adding scattered operations from which no returns were received. In addition to the American ores mined, nearly 1,000,000 tons of foreign iron ores were imported into the country. There was also considerable amounts of mill cinder, blue billy, franklinite slag, etc., used; but in tracing the ore from mine to furnace, these may be considered as being offset by the amount of iron ore which is used as fix in puddling and heating furnaces, as flux in silver smelting, and in the manufacture of paint, etc.

The table above shows the output of the different varieties and the total of all kinds of iron ore by States, and also the total of each kind of ore produced in the United States in the calendar year 1892. From this table it will be seen that of 16,296,666 gross tons of iron ore produced, of which there is authentic record, 11,646,619 gross tons was red hematite, 2,485,101 gross tons was brown hematite, 1,971,965 gross tons was magnetic ore, and the remainder, 192,981 gross tons, was carbonate ore. Compared with 1889, 1890 and 1891, the table on the next page shows the amounts of each class of iron ore produced, also the amount of increase or decrease, and the percentage of increase or decrease in 1892 and 1891. The figures for 1889 were collected for the eleventh census, those for succeeding years were obtained for the division of mining statistics of the U. S. Geological Survey.

This suggests a growing demand for red hematite iron ores at the expense of the magnetite and brown hematite varieties, but the advance in the amount of red hematite smelted is not so great as would appear from the table, as nearly

Production of Iron Ore, by Kinds, in Each State and Territory During the Calendar Year 1892.

States.	Red Hematite.	Brown Hematite.	Magnetite.	Carbonate.	Totals.
	Gross Tons.	Gross Tons.	Gross Tons.	Gross Tons.	Gross Tons.
Michigan	7,228,406	187,306	127,832	......	7,543,544
Alabama	1,657,028	655,043	......	......	2,312,071
Minnesota	1,250,465	5,000	......	......	1,255,465
Pennsylvania	163,307	229,700	685,986	5,054	1,084,047
New York	124,800	53,694	648,564	64,041	891,099
Wisconsin	774,879	15,300	......	......	790,179
Virginia	26,120	711,753	3,154	......	741,027
New Jersey	4,348	4,348	456,759	......	465,455
Tennessee	256,786	149,792	......	......	406,578
Georgia	30,835	154,219	......	......	185,054
Colorado	1,412	124,317	16,040	......	141,769
Missouri	114,032	4,462	......	......	118,494
Ohio	......	......	......	95,768	95,768
Kentucky	......	43,254	......	7,269	50,523
Massachusetts	......	44,941	......	......	44,941
Maryland	......	19,322	......	20,849	40,171
Connecticut	......	31,324	......	......	31,324
North Carolina	......	......	25,379	......	25,379
Texas	......	22,853	50	......	22,903
New Mexico	7,000	......	8,201	......	15,201
Oregon	......	11,503	......	......	11,503
Utah	2,301	8,800	......	......	11,101
Montana	4,900	2,170	......	......	7,070
West Virginia	......	6,000	......	......	6,000
Totals	11,646,619	2,485,101	1,971,965	192,981	16,296,666

all of the increased stock of ore at the close of 1892 was of the red hematite class.

The cause of the falling off in the brown hematite production was the low price of the rich Lake Superior ores, and the fact that nearly all of the brown ore has to be washed, thus increasing its cost. The magnetic ores (while sometimes richer in iron) are generally dense, and furnace operators claim that they require more fuel and care to smelt them, therefore, other things being equal, a blast-furnace manager usually prefers the softer hematites. The mines of magnetite in New York and New Jersey are also yearly becoming deeper, and the cost of winning the ores greater, for there laboring-saving devices are less liberally employed than in the Lake Superior region. These eastern mines have to bear not only the competition of the western ores, but also to meet that of foreign countries, and this fact has in late years caused the closing of a number of the eastern magnetic mines; the same is also true of some brown hematite mines near the seaboard. The amount of carbonate ore produced is so small that any local increase has quite a marked effect upon the total; the New York mines show an augmented output, due to the reopening of some old workings and the increased product of others. Ohio uses some of the local carbonates, but the main reliance of its large iron industry is upon hematite ores brought from the Lake Superior district.

COMPARATIVE PRODUCTION OF IRON ORE, BY KINDS, IN 1889, 1890, 1891 AND 1892.

KINDS OF ORE.	AMOUNTS PRODUCED.				DECREASE OR INCREASE IN 1892 AS COMPARED WITH 1891.	
	1892.	1891.	1890.	1889.	Amount.	Percentage.
	Gross Tons.	Gross Tons.	Gross Tons.	Gross Tons.	Gross Tons.	
Red hematite........	11,646,619	9,327,398	10,527,650	9,056,288	+2,319,221	+24.86
Brown hematite.....	2,485,101	2,757,564	2,559,938	2,523,087	—272,463	—9.88
Magnetite...........	1,971,965	2,317,108	2,570,838	2,506,415	—345,143	—14.89
Carbonate	192,981	189,108	377,617	432,251	+3,873	+2.05
Totals..........	16,296,666	14,591,178	16,036,043	14,518,041	+1,705,488	+11.69

LOCATIONS OF IRON ORE MINES.

The States of New York, New Jersey, Michigan, Wisconsin, Minnesota, Alabama, North Carolina, Georgia, and possibly Missouri, mine iron ores in excess of the demands of their present active smelting capacities, while Pennsylvania, Ohio, Kentucky, West Virginia, Tennessee and Maryland each consume more iron ore in blast furnaces than they produce. The ores from the Lake Superior districts supply the blast furnaces in Michigan, Wisconsin, Minnesota, Illinois, most of those in Ohio, West Virginia, Western Pennsylvania and part of those in the States of New York and Kentucky and Eastern Pennsylvania.

The foreign iron ores imported are chiefly used by blast furnaces in Pennsylvania and Maryland, some ores being at times supplied to New York and New Jersey furnaces. A small amount also comes to Pacific Coast ports.

The economies introduced for mining, handling and transporting by rail and water permits the Lake Superior iron ores to meet foreign ores (which pay a duty of seventy-five cents per ton) within less than 100 miles of Atlantic ports at equal prices per unit of iron,

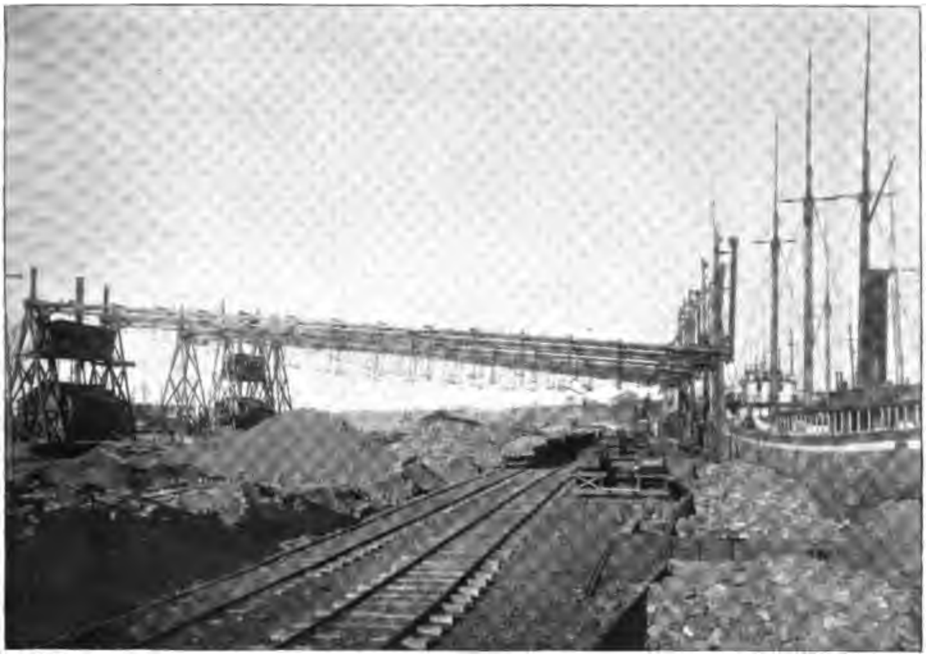
While Michigan has for years maintained the lead as a producer of iron ores,

and made advances in production, the older Marquette range has not been holding its own with the Gogebic range in the western part of the State. Some of the more noted Marquette mines have decreased outputs, and others may be closed, owing to the low price of ore and competition with the softer and more cheaply mined ores of the Gogebic and Mesabi ranges. An interesting feature in connection with the exploitation of the Marquette range is the draining of Lake Angeline, near Ishpeming, Mich., in order to obtain the ore which lies beneath the lake to better advantage.

Besides being the greatest contributor to the iron ore supply, Michigan has the credit of furnishing the largest annual output from one operation. A list of mines producing in 1892 50,000 tons or over shows that thirty-two of the largest mines are credited to this State. The workings of what are known as the Norrie, the East and North Norrie mines, are connected, extending for a length of three-fourths of a mile, while they reach a maximum depth of 650 feet. The Norrie mine, first opened in 1885, has produced up to the close of the year 1892, 4,113,103 gross tons.

Alabama continued in second place in 1892, with an increased output of iron ore, viz., 2,312,071 tons, or 14.19 per cent. of the total for the country, of which 1,657,028 tons, or 71.67 per cent., was red hematite and 655,043 gross tons, or 28.33 per cent., brown hematite.

Minnesota, in order of precedence, passed both Pennsylvania and New York in 1892, occupying third place, with an iron ore output of 1,255,465 gross tons, or 7.70 per cent. of the total for the United States. With the exception of 5000 tons of ore classed as brown hematite mined in the Mesabi range, but not shipped last year, the whole of this amount was red hematite ore, the State also ranking third as a producer of this class of ore, with 10.74 per cent. of the total for the country.



BROWN HOISTING AND CONVEYING MACHINERY FOR LOADING ORE VESSELS.

The year 1892 chronicles the first shipment (4245 gross tons) from the new Mesabi range in Minnesota. Although there was a considerable amount of iron ore mined, much of it was stocked on account of lack of railroad transportation.

Pennsylvania has fallen from third to fourth position, as to iron ore output, the product of 1,084,047 gross tons being but 6.55 per cent. of the total for the United States, showing a decrease of 188,881 tons, or 14.84 per cent. from the 1891 output of 1,272,928 gross tons. This decline was in all of the varieties of iron ore except red hematite.

Of the 1892 output 63.28 per cent. was magnetite, 21.19 per cent. brown hematite, 15.06 per cent. red hematite and 0.47 per cent. carbonate, giving the State first place as a producer of magnetite, with a credit of 34.79 per cent. of the country's total; third place in the mining of brown hematite ores, with 9.24 per cent. of the total of that class of ore, and sixth and fifth places in the red hematite and carbonate varieties, with 1.40 per cent. and 2.62 per cent. of the respective totals. Pennsylvania's position as an iron-ore producer and its first rank among the contributors of magnetite is due to the large deposit of ore in the Cornwall Ore Hills, the cheap mining of which on a large scale places this property among the great mines of the country.

New York, like Pennsylvania, produced the four classes of iron ore, and these two States were the only ones winning all the different characters of ore last year. The 1892 output was 891,099 gross tons, a decline from that of 1891 (1,017,216 tons) of 126,117 tons or 12.40 per cent. This restricted product was confined to the magnetic and red hematite varieties of ore, the other two classes showing an increase. The State occupies second place as a producer of magnetic iron ore, 648,564 gross tons, or 32.89 per cent. of the total for the United States, being of this character. There is but a slight difference in the magnetite outputs of Pennsylvania and New York, the former now taking first place, but approximately the annual production of magnetic iron ore in the United States may be considered as being in three nearly equal parts, slightly more than one-third coming from Pennsylvania, and the balance being about

BOG IRON ORE MINING, NEAR NEW BIRMINGHAM, TEXAS.

AN ORE HOISTING AND CONVEYING PLANT.

equally divided between New York and other States. The red hematites, in which class New York occupies seventh place, with 1.07 per cent. of the country's total, also shows a falling off of 28,923 tons, or 18.82 per cent. from the 1891 product of 153,723 gross tons. The brown hematite mines produced 53,694 tons in 1892, an increase over the 1891 total (53,152 tons) of 542 tons, or 1.02 per cent., giving the State eighth position, with 2.16 per cent. of the country's total. The carbonate ores show a decided advance from 27,612 gross tons in 1891 to 64,041 tons in 1892, this gain of 36,429 gross tons or 131.93 per cent. being due to the re-opening of old mines and more active operations in other properties in the Southeastern portion of the State near the Hudson River. One-third of all the carbonate ore produced in the United States was supplied by New York, in which class of ore the State occupied second place. New York has some important producers which have supplied and can again furnish ore much in excess of the quantity credited to them last year.

The major portion of the iron ore won in Wisconsin came from the mines near Hurley on the Gogebic range, and those on the Menominee range in the vicinity of Florence, the total being 790,179 gross tons, an advance over the 1891 figures (589,481 gross tons) of 200,698 gross tons, or 34.05 per cent. All the ore mined in 1892, with the exception of 15,300 tons of brown hematite, was of the red hematite variety, in which class the State occupied fourth place, supplying 6.65 per cent. of the total for the United States. Wisconsin will probably augment the output of brown hematite in future years to supply local blast furnaces.

Virginia ranks seventh as an iron ore producer, with 741,027 gross tons, or 4.55 per cent. of the total for the United States in 1892. Of the State's total 711,753 gross tons, or 96.05 per cent., was of the brown hematite variety, giving the State first place as a producer of this class of ore, with 28.64 per cent. of the total for the entire country. Of the balance, 26,120 gross tons was red hematite ore and 3,154 tons magnetite.

New Jersey occupied eighth place, producing 465,455 gross tons of iron ore or 2.86 per cent. of the country's total. Of this amount, 456,759 gross tons consisted of magnetic ores, giving the State

third place in this class of ore, with 23.16 per cent. of the total for the United States. The balance, 8,696 gross tons, was about equally divided between the red and brown hematites.

Tennessee shows a decrease in the amount of iron ore mined in 1892 of 137,345 gross tons, or 25.25 per cent., the figures for 1892 being but 406,578 tons, as compared with 543,923 gross tons won in 1891. Of the amount mined in 1892, 63.16 per cent., or 256,786 tons, was red hematite ore, and the balance, 36.84 per cent., or 149,792 tons, was brown hematite. In this State, as in New Jersey, New York, Pennsylvania, Virginia, and other States, the total annual output of a certain variety of iron ore may be seriously affected by the activity of blast furnace plants which are supplied by local mines controlled by the owners of iron works.

EXPLORER'S CAMP IN LAKE SUPERIOR MINING REGION.

Georgia, Colorado, and Missouri were the only other States which produced over 100,000 tons of ore in 1892, their outputs being 185,054, 141,769, and 118,494 long tons respectively, giving them tenth, eleventh, and twelfth places. The major portion of Georgia's output was brown hematite ore, the remainder red hematite. Colorado's product was also nearly all of the brown hematite class, but small amounts of magnetite and red hematite ores were also won. Its iron ore output was divided among the blast furnaces and the silver smelters, the use in the latter being as a flux. Approximately forty-three per cent. of the Colorado iron ores were converted into pig iron and fifty-seven per cent. used as a flux. With the exception of a small amount of brown hematite, all of Missouri's iron ores were of the red hematite variety, the brown hematite being sold to silver smelters.

Ohio heads the list of carbonate iron ore producers with 95,768 gross tons, or 49.63 per cent. of the total for the entire country, this being the only class of ore which was mined. Most of the ore smelted in Ohio blast furnaces comes from the Lake Superior regions.

The other States and Territories mining iron ore in 1892, were Kentucky, Massachusetts, Maryland, Connecticut, North Carolina, Texas, New Mexico, Oregon, Utah, Montana, and W. Virginia. Kentucky's contribution was mainly

brown hematite ores, although some of this was weathered carbonate, classed as brown hematites, the native ores being enriched by liberal mixtures of Lake Superior iron ores.

The ore won in Massachusetts and Connecticut was of the brown hematite variety, and came chiefly from the celebrated Salisbury district.

In the Eastern part of Maryland carbonate ores were obtained, while the Western section contributed brown hematite ores.

The major portion of North Carolina's output was magnetite from the Cranberry district.

The brown hematite ores of Texas came from the Eastern and South Central portion of the State, the magnetite being a few car-loads which were sent from the Llano district for trial in the blast furnace. While this district has good iron ores, the lack of railroad transportation and a convenient market has prevented its earlier development, but in the future it is expected to prove the source of a good supply of Bessemer iron ore.

All of the ore won in New Mexico, Montana, and Utah was used as a flux in silver smelting, and was mostly brown hematite, although magnetite and red hematite were also mined.

Oregon's brown hematite ore was used at the furnace of the Oswego Iron and Steel Company, and the output of West Virginia was also consumed in the blast furnaces of the State.

It is reported that some of the excellent iron ores of Wyoming are being exploited, and that about 5,000 tons of ore were taken out and stocked for future shipment.

AMOUNT AND VALUE OF IRON ORE PRODUCED IN THE CALENDAR YEAR 1892.

STATES.	Amounts produced.	Total value of ore at mine.	Average value per ton of ore at mine.
	Long Tons.		
Michigan	7,543,544	$16,587,521	$2.20
Alabama	2,312,071	2,442,575	1.06
Minnesota	1,255,465	3,090,942	2.46
Pennsylvania	1,084,047	2,197,028	2.03
New York	891,099	2,379,267	2.67
Wisconsin	790,179	1,428,921	1.81
Virginia and West Virginia	747,027	1,428,801	1.91
New Jersey	465,455	1,388,875	2.98
Tennessee	406,578	505,359	1.24
Georgia and North Carolina	210,433	262,517	1.25
Colorado	141,769	587,903	4.15
Missouri	118,494	237,827	2.01
Ohio	95,768	148,288	1.55
Massachusetts and Connecticut	76,265	249,198	3.27
Kentucky	50,523	63,172	1.25
Maryland	40,171	88,691	2.21
Texas	22,903	20,890	0.91
Other States	44,875	97,121	2.16
Totals	16,296,666	33,204,896	2.04

VALUE OF ORES.

The value of the iron ore produced during the year 1892, as set forth in the above table, represents the average market value of the ore for the year, less freight or other transportation charges, commissions, etc.; that is, the figures give the average value of the ore (including royalty, if any) delivered on cars or other vehicles at the mine. The variation exhibited by this value in the different States is affected by the quality of the ore won, and the distance of the mines from points of consump-

tion. This would be still more evident by a comparison of districts, of groups of mines, or of single mines, but as a rule the average value of ores is a fair indication of their yield in iron, or their relative absence of deleterious ingredients. In the West the high valuation, however, is due to the increased cost of labor.

The most important source of our ore supply next the Lake Superior region and Alabama is foreign, some of this foreign ore coming from our neighbors, Canada and Cuba, but the larger portion from Spain, Africa, the Island of Elba, Greece, France and other countries across the ocean.

Next to the foreign ores, the Cornwall ore banks of Pennsylvania rank as a source of supply, followed by the Lake Champlain district, large quantities of magnetic ore being taken from the mines at Plattsburgh, Port Henry and Crown Point in New York State.

The ores from the different districts vary in the yield of iron, and it is therefore of interest to place the sources in something near their relative rank by estimating the probable percentage of the total amount of pig iron which they yielded. Such an estimate was prepared for the year 1887 and shows the proportions about as follows:

	Per Cent.
Lake Superior ores	44
Foreign ores	10½
Lake Champlain ores	6½
Cornwall ores	5—
Alabama ores	5—
New Jersey ores	4½
Tennessee ores	4
Missouri ores	3½
Virginia ores	3—
Ohio ores	2½
Salisbury Region	1—
Georgia ores	½—

While it is impossible to give the exact percentages for the year 1892 for all of the districts mentioned above, the following will indicate some of the changes which have taken place in five years. Probably sixty per cent. of the pig iron is produced from ores obtained from the Lake Superior district, those mined in the Southern States of Alabama, Georgia and Tennessee furnish seventeen per cent., while the foreign iron ores yielded about five per cent., and the Cornwall ores three per cent. of the total pig iron output of the country.

BOILERS AT THE WORLD'S FAIR.

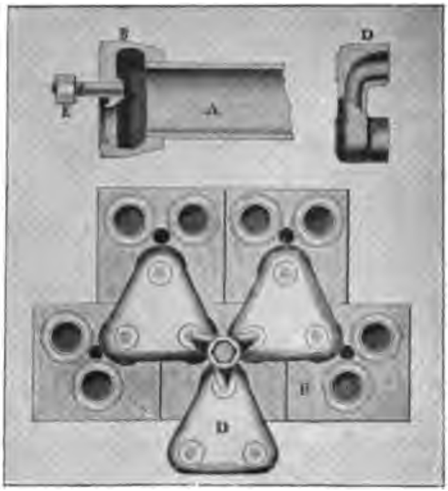
By H. W. York, Chief Eng. United Electric Light and Power Co

First Paper.

TO the thoughtful spectator in Machinery Hall at Chicago, with its maze of intricate apparatus, humming and buzzing in apparently ceaseless motion, the subject of boilers and steam raising suggests itself at once as of primary interest and importance. The whole vast display of engines and tools, electric dynamos and motors, and the thousand and one pieces of machinery in operation, lending an air of life and activity to the exhibit, depend upon steam for their effectiveness, and one's thoughts involuntarily revert to the boiler house and its equipment as the foundation source of the tremendous accumulation of power of the existence of which such striking demonstration is afforded. Altogether, a power equivalent, in an engineering sense, to that of about 30,000 horses is there concentrated—a power of which it is difficult for the lay mind to form an adequate conception, and which appeals in a somewhat indefinite way only even to the engineer. The impression is firmly fixed, however, that the available energy is extraordinary in amount, and certainly it is when we bear in mind that it is not equaled nor even approached in any other steam plant in existence.

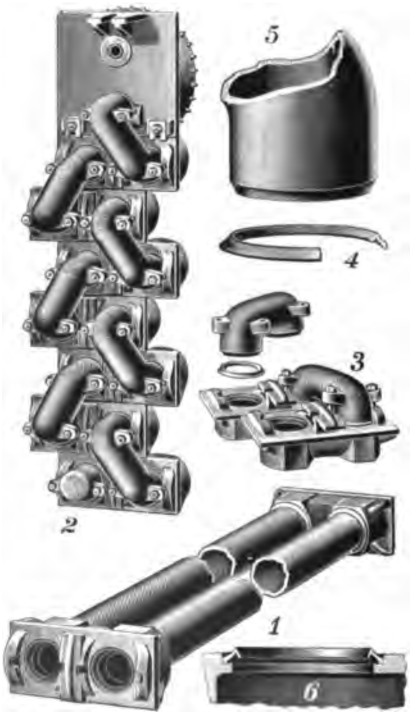
A boiler horse-power, roughly speaking, means about thirty pounds of water evaporated into steam per hour, and for this about three pounds of coal are needed, so that the concentrated power in the Fair Grounds entails, approximately, a total hourly consumption of nearly a million pounds of water and an equivalent of something like forty-five tons of coal, though, as may perhaps be generally known at this time, coal is entirely dispensed with under the Fair boilers, and oil alone is used as fuel. The handling of such a prodigious quantity of coal, however, would keep not far from 100 men actively employed at one time, steadily feeding the gaping mouths of the dozens of fiery furnaces, while the water volume used per hour, if steadily supplied for a whole day, would be sufficient to amply satisfy the needs of a fair-sized town, of say about 25,000 inhabitants, providing for each person the liberal allowance of about 100 gallons per day. The steam boilers, then, shown at the Fair are, as previously intimated, certainly second to none of the engineering exhibits in point of importance, and to the student of boiler design are objects of interesting, comparative analysis, all of them being of the sectional or water tube type. This particular feature of the whole boiler plant was the natural outcome of one of the conditions—that of safety—which governed the concentration of so great a power in so comparatively small a space, with thousands of human lives constantly in close proximity. No possibly avoidable risks of explosions were to be taken, and the water tube type of boiler was, therefore determined upon as the only properly admissible one, having shown itself by years of practical demonstration to be the only one likely to meet the exacting safety requirements of the present case.

It may not be uninteresting at the present time to recall the fact that at the Centennial Exhibition at Philadelphia, in 1876, fifteen different styles of boilers were shown, nine of them belonging to the sectional and the water tube classes. In the course of years since then, four of these have gone out of the market, and the Babcock & Wilcox, the Root, the Harrison, the Corliss and the Galloway boilers alone remain in active competition ; but of these older boilers only two, the Babcock & Wilcox and the Root, are represented at Chicago, though a number of others, the outgrowths of more recent years, have been added to them, so that the whole exhibit comprises eight different makes. It seems natural enough that in describing the various boilers the more time-honored ones should be given preference in the order of presentation ; hence the propriety of beginning with the Root and the Babcock & Wilcox boilers, and of referring also to some extent to the Centennial designs, as they may be called, of these two.

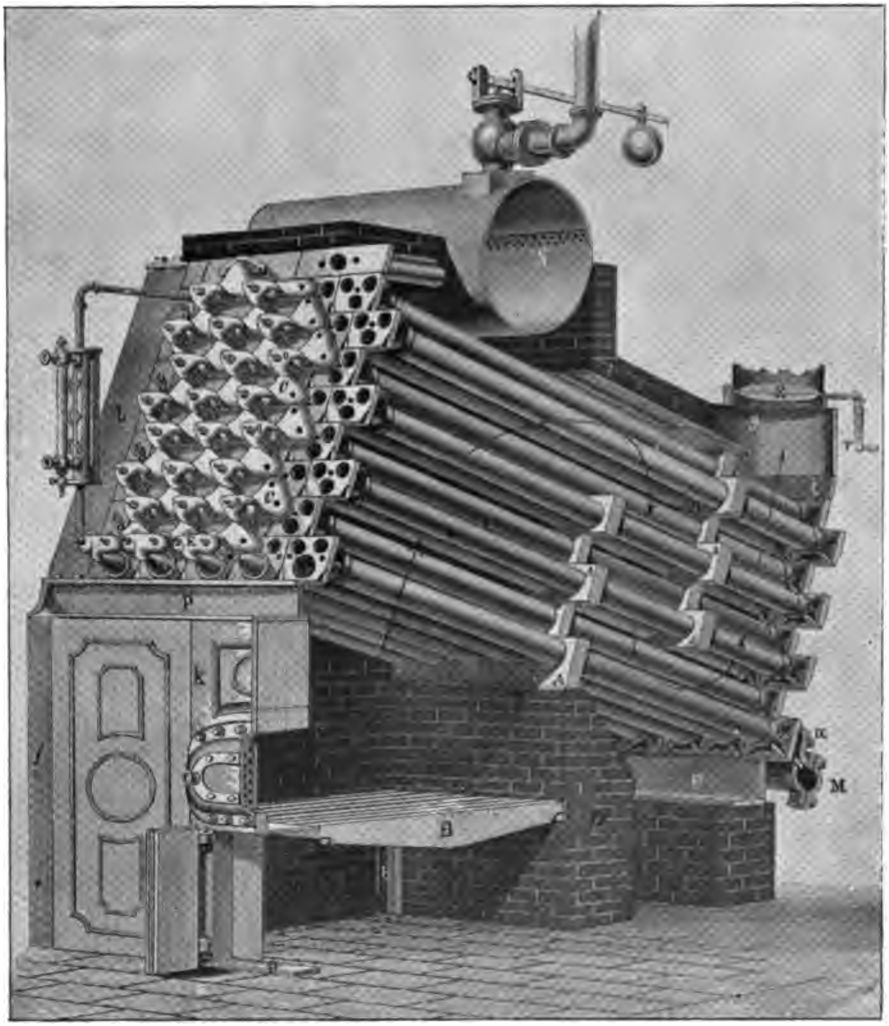


HEADER DETAILS OF THE ROOT CENTENNIAL BOILER.

Concerning the early Root boiler, the engraving on the opposite page leaves little to be explained. The tubes were inclined in that design as they are in the one of to-day, but the water level was carried at a point below the front ends of the top tubes. These ends, as will be understood, therefore contained only steam, and the latter was delivered into a large transverse drum located high up beyond the water line, and from it the main steam supply pipe was taken. The feed connection was made at one end of the blow-off pipe M, while the blow-off cock was attached to the other end, the water thus being introduced at the coolest portion of the boiler and gradually reaching the more highly heated parts. The front and rear connections of the tubes —always points of special interest and importance in boilers of this class—are shown in detail and were exactly alike, each tube having a square, box-like header, into which it entered at the rear. The front side of each header was provided with three openings which were connected with similarly disposed openings in adjoining headers by trian-



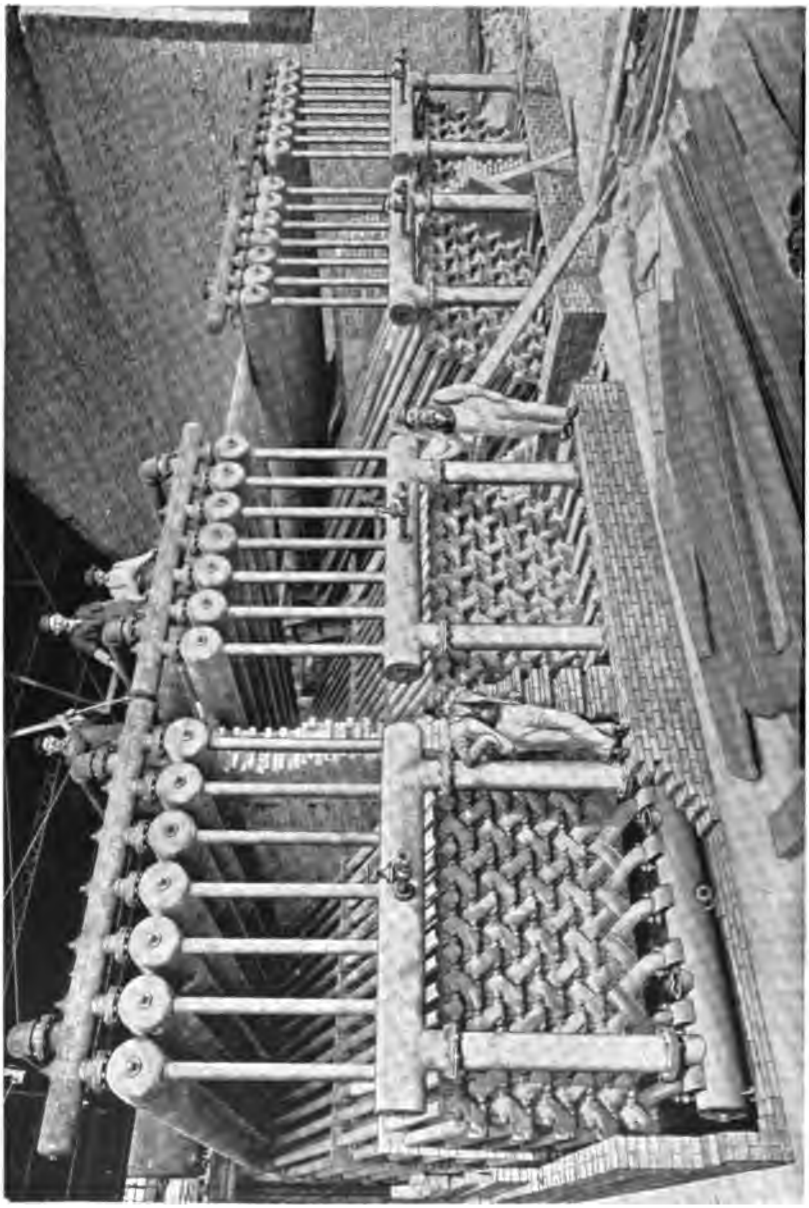
HEADER DETAILS OF THE IMPROVED ROOT BOILER.



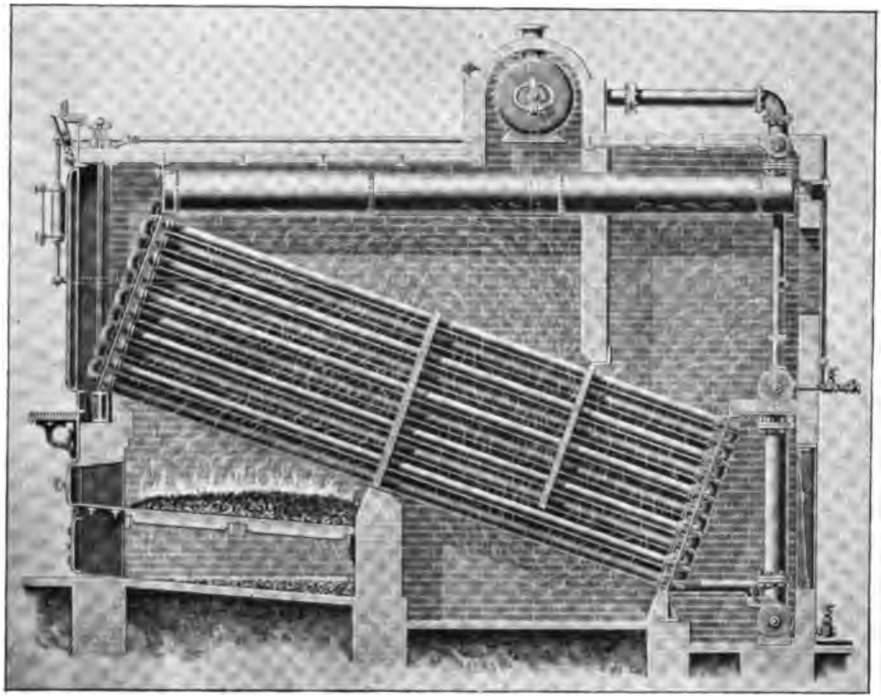
THE ROOT BOILER, MADE BY THE ABENDROTH & ROOT MFG. CO., NEW YORK. DESIGN SHOWN AT THE CENTENNIAL EXHIBITION, AT PHILADELPHIA, 1876.

gular caps held in place by bolts as shown. The lower course of tubes had larger headers, and the bottom openings of these were of the same size as the tubes themselves.

While this boiler was of an excellent type, and remarkably good performances were achieved with it, subsequent experience prompted various modifications, the extent of which can be best appreciated by an examination of the several illustrations of the Root boiler of to-day, as exhibited at Chicago. From these illustrations it will be seen that the design went through a process of pretty thorough transformation. The inclined tube system, of course, was retained, but the tubes in the improved boiler are completely submerged and the water-line is carried in a series of longitudinal drums of comparatively small diameter. The boiler, as a little study will show, has been thoroughly divided up into sections, so that the



REAR VIEW OF ROOT BOILERS IN PROCESS OF ERECTION IN BOILER HOUSE OF THE WORLD'S COLUMBIAN EXPOSITION, CHICAGO.

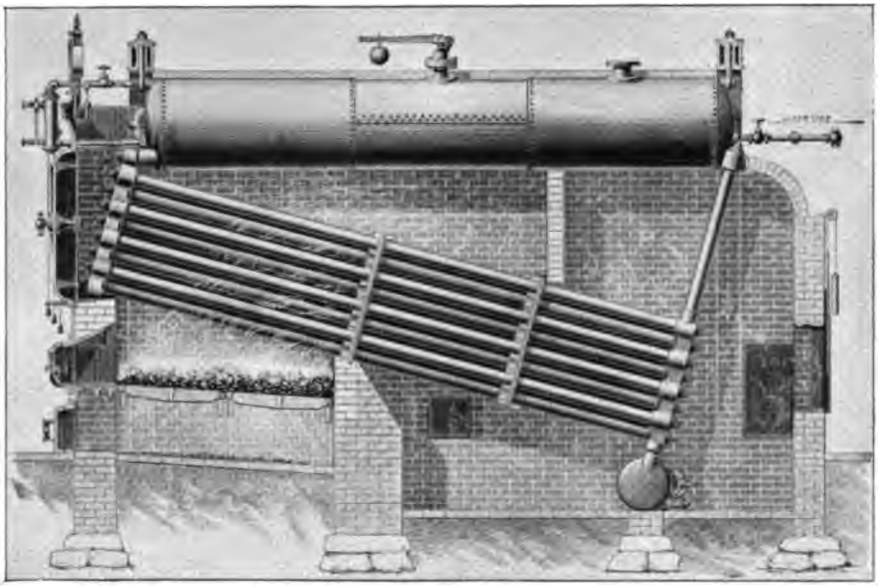


SIDE ELEVATION OF ROOT BOILER EXHIBITED AT CHICAGO.

makers' claim of building a sectional boiler is well borne out by facts; for each vertical section of tubes there is one of the longitudinal drums above mentioned, and all these drums are connected on top at their rear ends by a cross connection or drum from which again pipes lead to the main steam drum running transversely across the top of the whole boiler. This arrangement is probably best shown in the side elevation and section of the setting.

From the lower side of the rear ends of the longitudinal steam and water drums drop tubes descend and enter another transverse drum into which the feed water is admitted. This drum finally is connected by two large pipes to still lower cross drum, constituting the mud drum, and this, in turn, is connected to the various tube sections of the boiler. The feed water, it will be observed, is introduced at a most advantageous point, increasing the natural downward circulation at that point of the water already in the boiler, because of its comparatively great density when admitted at its relatively low temperature, and becoming thoroughly mixed with the hot water before reaching the more highly heated parts. From the nature of the connection, as shown in the side elevation, it becomes clear that as the water enters the tube system proper at the bottom, the lower rows of tubes are always assured of a continuous supply and there is, thus, no danger of overheated surfaces and damaged tubes.

The header connections and accessories are shown in one of the illustrations on page 258, the part marked 1 representing what the makers call a "package" of tubes, and consisting of two tubes with a header expanded on each end. No. 2 shows several of these packages placed on top of one another, forming a regular section. The headers

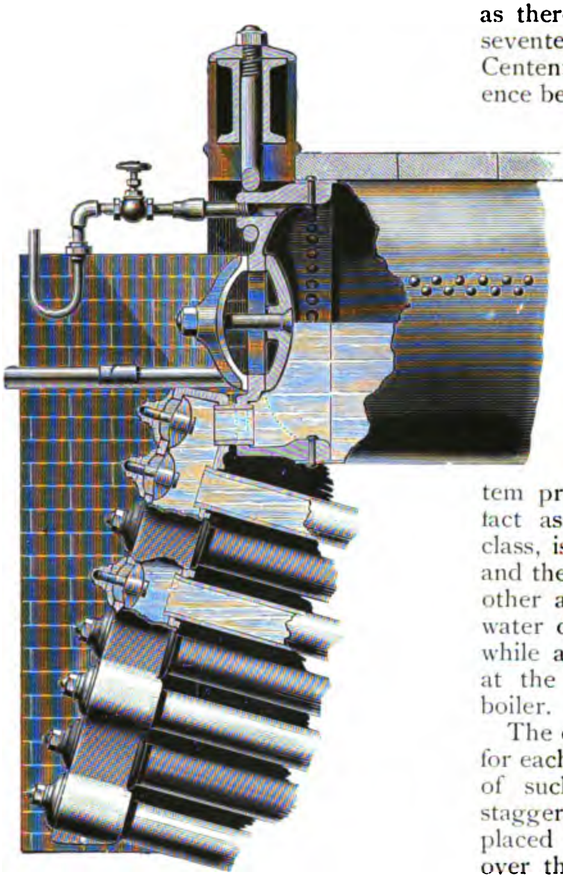


SIDE ELEVATION AND SECTION OF THE BABCOCK & WILCOX BOILER, MADE BY THE BABCOCK & WILCOX CO., NEW YORK.

of these several packages are connected by bends through which ready circulation of water is obtained from the bottom to the top of each section. A number of the latter, placed side by side, make up a complete boiler. The method in which the connecting bends just spoken of are applied is shown in No. 3. At the right is seen one connecting bend in place, while a second connecting bend at the left is shown ready to drop into place. Between the bend and the header is a metallic packing ring which drops into the seat beneath it. This ring is shown in detail in No. 4, and a sectional view in No. 6 shows it in place. All the seats are most carefully milled out to an exact size by special machinery and the ring, which is made of an extremely elastic bronzelike metal, is also finished on special machinery to an exact size, so that any ring is guaranteed to fit perfectly into every seat. The tapered end of the connecting bend is shown in the enlarged view, No. 5, and when this plug is forced down into the tapered seat of the ring, it will cause the latter to expand in every direction radially and so make an absolutely tight joint. The bend is drawn down into the seat by bolts. The head of these bolts are ball shaped and are received into similar shaped sockets cast in the headers, which allow the screw ends freedom to move in every direction. It will be seen from all this that the boiler can be put together or taken apart without much trouble, and repairs can thus be easily and quickly made.

An important feature of the whole arrangement is that it provides a very flexible vertical section. It is known that the tubes in the lower rows are elongated more than the tubes in the upper rows, on account of their close proximity to the fire, and it is readily seen that if this section were rigid and inflexible, the difference in length of tubes contained in the boiler would put upon the vertical sections severe strains, which would constantly have a tendency to rupture them. Each package of tubes is comparatively small in bulk and weight, and thus is easily handled. As these packages are piled up in a

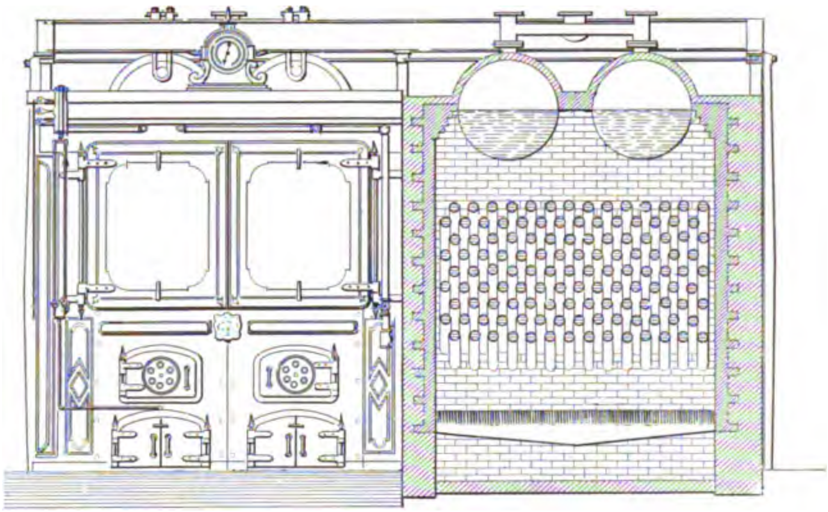
boiler in a similar manner to the bricks in a wall, that is, so that all of their vertical joints are broken, it is readily seen, that after taking off two connecting bends in the front and two in the rear, any one of these packages can be pulled out and removed without disturbing those above or around it, the same as a brick can be removed from a wall, and another package can easily and quickly be inserted in its place. In the erection of the Root boiler the front end is supported from iron girders and columns while the rear rests upon an iron saddle in the setting, substantially as shown in the side elevation. Four of these boilers, rated at about 1150 horse-power, are exhibited by the Abendroth & Root Mfg. Co., and have elicited much favorable comment because of their finely finished appearance.



BABCOCK & WILCOX HEADER DETAIL.

The Babcock & Wilcox Co. are represented at the Fair by five batteries of their boilers in the main plant, three boilers being in each battery, while a further number are located at the station of the Intramural Railway. In the main, the Babcock & Wilcox boiler of to-day, as there shown, is the same as that of seventeen years ago as seen at the Centennial Exhibition, the only difference being that the Centennial boilers had transverse drums across their tops and were provided with three and one-half-inch tubes, sixteen feet long, while in the present design there are no such cross drums, and the diameter of the tubes is four inches, while their length has been increased to eighteen feet. In the setting of the boilers, also, rolled iron is now used in place of the cast-iron columns and arches of earlier years. The tube system proper, as in the Root boiler, in fact as in most boilers of the same class, is placed in an inclined position, and the tubes are connected with each other and with a horizontal steam and water drum by passages at each end, while a mud drum connects the tubes at the rear and lowest point in the boiler.

The end connections are in one piece for each vertical row of tubes, and are of such form that the tubes are staggered, or, in other words, are so placed that each horizontal row comes over the spaces in the previous row. The tubes are fitted into the headers by expanding. The sections thus formed are connected with the steam and water drum, and with the mud drum also, by short tubes expanded into bored holes, doing away with all bolts and leaving a clear passageway between the several parts. The openings for cleaning, opposite the end of each tube, are closed by hand-hole plates, the joints of which are made by milling the surfaces to accurate metallic contact.



FRONT ELEVATION AND CROSS SECTION OF BABCOCK & WILCOX BOILER.

The plates themselves are held in place by wrought iron, forged clamps and bolts.

In erecting the boiler, it is suspended entirely independent of the brick work from wrought-iron girders resting on iron columns, thus avoiding any straining of the different parts from unequal expansion between them and the enclosing walls, and permitting the brick work to be repaired or removed, if necessary, without disturbing the boiler itself. The feed water is led directly into one end of the large steam and water drum, and from the top of this also the steam supply is taken.

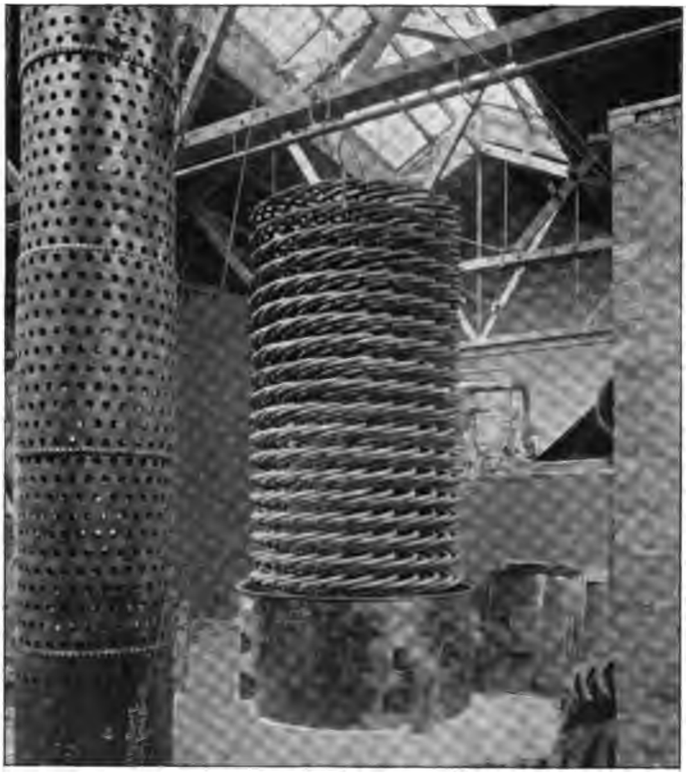
Generally speaking, the character of the circulation of the water in all the boilers of this type may be said to be similar. The furnace end is under the front and higher ends of the tubes and the products of combustion pass more or less circuitously from there into the chimney flue. The water in the tubes, as it is heated, tends to rise toward the higher ends, and, as it is converted into steam, the mingled column of steam and water, being lighter than the solid water at the back ends of the boilers, rises through the front connections into the drums above the tubes, where the steam separates from the water and the latter flows to the rear and down again through the tubes in a continuous circulating current.

Among the various steam generators, known in a general way as "pipe boilers," which have appeared on the market within the past few years, that known more specifically as the Morrin or "Climax" boiler, has come rapidly to the front, and has done good work in a number of different places. Three boilers of this make—two of 500 and one of 1000 horse-power—are on exhibition at the Fair, those of 500 horse-power being each thirty feet high and thirteen feet in diameter, while the 1000 horse-power boiler, claimed to be the largest boiler in the world, is fifteen and one-half feet in diameter, and has a height over all of thirty-seven feet. This last generator contains 1000 three-inch tubes, each twelve feet long, which, if placed in one continuous length, would extend over nearly two and one-half miles. The heating surface amounts to 10,000 square feet, and the boiler is guaranteed to evaporate 30,000 pounds,

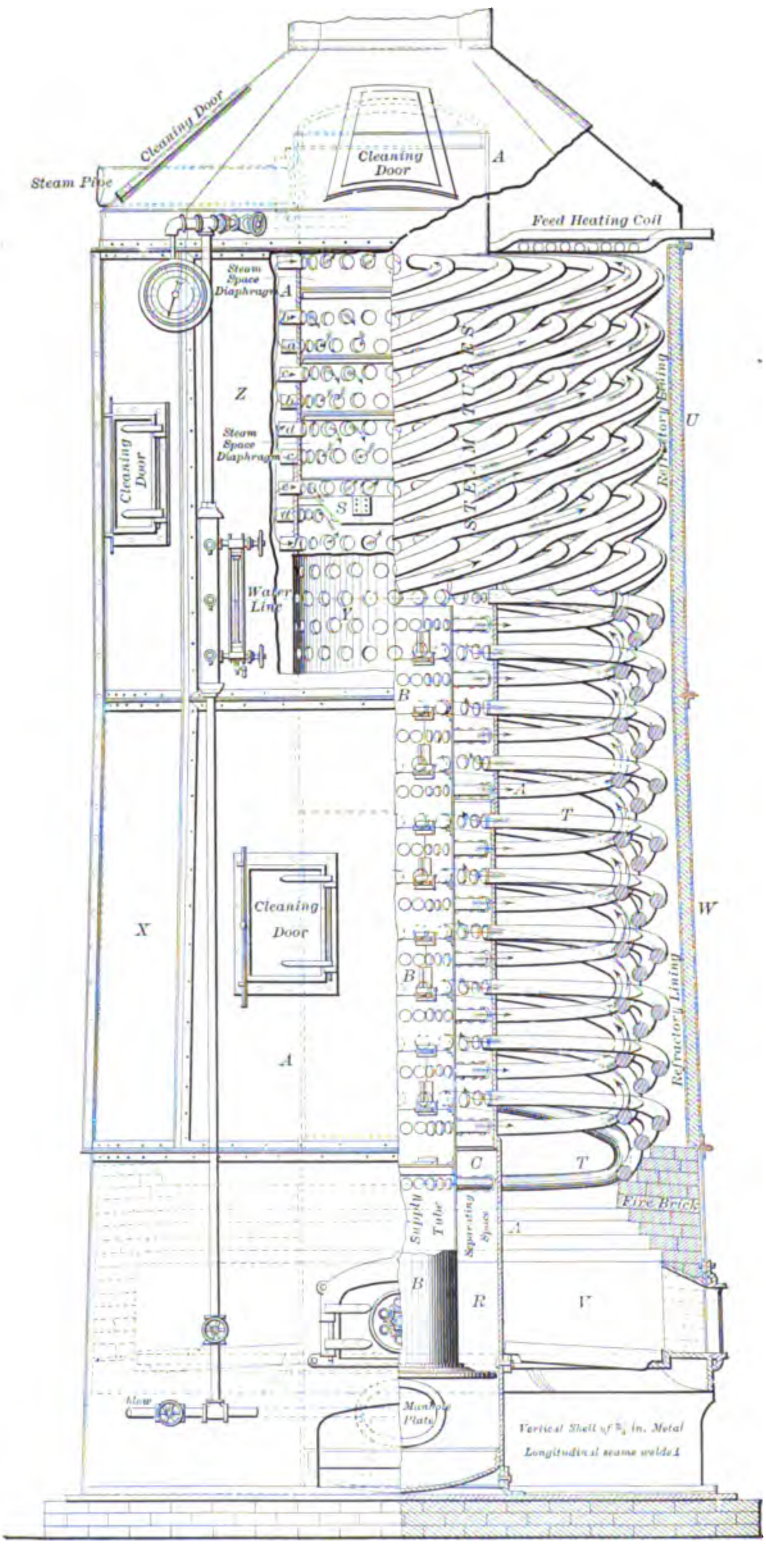
B. & W. HEADER.

or about fifteen tons of water into dry steam every hour. The two smaller of the three boilers are boilers which have been in service for the past eight years, and are exactly the same as originally built, no change whatever having been made in the design. The proportion of grate to heating surface adopted is one to fifty.

One of the accompanying illustrations represents a cylinder of one of the boilers without the tubes, showing simply the holes drilled for their insertion, and also a boiler with the outside casing removed. A side elevation with and without the casing, a vertical section through the centre of the boiler, and a horizontal section are given in the two other illustrations. While at first glance the boiler appears complicated, a closer examination shows it to be really quite simple. The generator proper consists simply of the loop-like tubes *T*, and a vertical cylinder *A*, extending throughout the whole height of the generator. The construction of this cylinder is similar to that of any ordinary cylindrical boiler shell ; that is to say, it is made perfectly steam-tight, also strong enough to resist the internal pressure, and is provided on top with the usual manhole plate. A better idea of the form of the loop-like tubes *T* may be obtained by referring to the shaded tubes in the horizontal section. The extremities *E* and *F* of these tubes extend, and are expanded into the shell of the cylinder *A*, so as to make them perfectly steam-tight ; their ends *F*, *F* are in higher planes than their



THE CLIMAX BOILER, MADE BY THE CLONBROCK STEAM BOILER WORKS, BROOKLYN, N. Y.



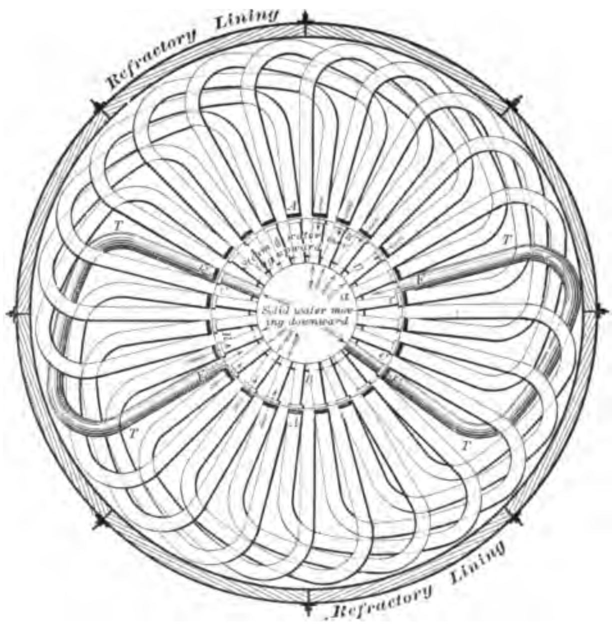
ELEVATION AND SECTION OF THE CLIMAX BOILER.

ends E, E, as will be seen by referring to the lower shaded tube in the vertical section.

Within the cylinder A is another cylinder B, open at both ends. The bottom of this rests on brackets riveted to the outer cylinder, and the upper end of cylinder B extends about up to the water line. The cylinder B is in fact a built-up one, being made in short sections, so that they can be readily removed when repairs are necessary. Since the pressure inside of the cylinder B is equal to the pressure outside of it, comparatively light iron is used in its construction. The joints of the sections need not be steam-tight, and consequently they are held together simply by means of a few bolts. It will be seen that the lower ends E of the tubes T are connected to the inner cylinder B by short tubes C, crossing the annular space R, R. These short tubes C are simply driven into the tubes T; their other ends rest in the holes through the cylinder B. The ends of the short tubes need not be, and are not expanded, as perfect steam-tight joints are not necessary.

The fire-box surrounds the cylinder A, and is annular in form. The casing U, W is made in sections, bolted together.

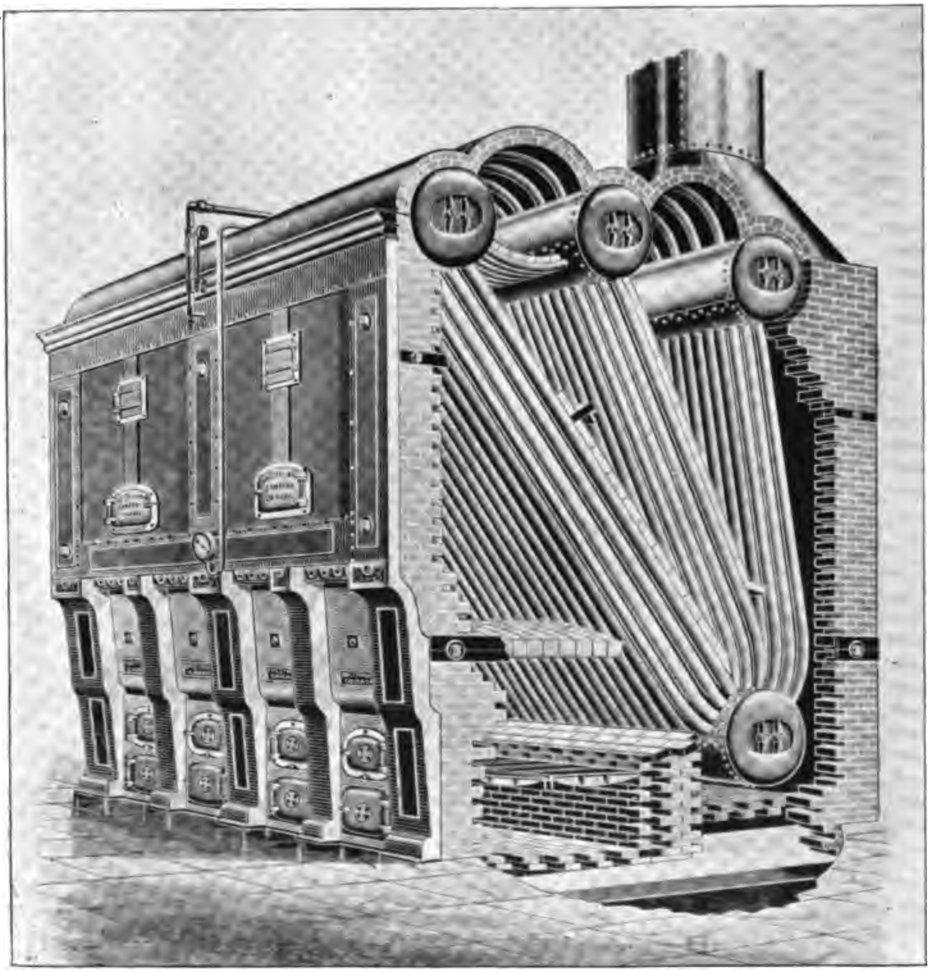
This arrangement allows any one of the sections, such as X for instance, to be removed without disturbing the other sections, when it is necessary to replace a tube. Sometimes the inside of the casing is lined with terra-cotta, and in such cases the inner plates for the refractory lining shown in the illustrations are not used.



HORIZONTAL SECTION OF THE CLIMAX BOILER.

The action of the steam generator will be easily understood. The water, as it is heated, will ascend in the loop-like tubes T, flow into the annular space R, and a fresh supply of water is drawn from the inner cylinder B. In this manner a constant circulation is maintained in the tubes T, causing the steam and water in the annular space R to ascend and the solid water in cylinder B to descend. The deflector S, directly above cylinder B tends to de-

posit any water that may be carried by the steam. The tubes above the water line will dry and superheat the steam; the diaphragm plates above the de-



THE STIRLING WATER TUBE BOILER, MADE BY THE STIRLING COMPANY CHICAGO, ILL.

flector compel the steam to circulate, in succession, through each tier of the steam and drying tubes. The feed water in entering the generator has to flow through the coil resting on the upper tier of tubes, and is well heated before it mingles with the water in the generator.

Since the largest diameter exposed to bursting pressure is the comparatively small vertical cylindrical shell, it will be seen that these generators can be made of large power and still be entirely safe under any pressure desired. When worked under ordinary pressures the factor of safety is high. The boiler was invented by T. F. Morrin, chief engineer of Lorillard's tobacco factory at Jersey City, N. J., and is built by the Clonbrock Steam Boiler Works, of Brooklyn, N. Y.

Differing considerably from the two

boilers just described is the Stirling boiler, one of the later forms of water tube boiler, with which a most creditable exhibit is made by the Stirling Company, of Chicago, Ill., consisting of practically three separate plants aggregating 2800 horse-power. One of these is located in the main boiler room, and comprises two batteries, each of two boilers, and each boiler rated at 400 horse-power. The second, in the boiler room annex, is made up of one battery of two boilers, each of 400 horse-power; and the third, finally, consisting of one battery and two boilers of 200 horse-power each, is in operation at the Libbey Glass Company's exhibit in the Midway Plaisance. The boiler consists of three upper steam drums and one lower mud drum, respectively thirty-six and forty-two inches in diameter, all connected by means of three and one-fourth-inch tubes, which are expanded directly into the drums, and so bent as to allow for the varying degrees of expansion and contraction. In one end of each drum is a sixteen-inch manhole, faced elliptically, against which a plate may be fitted and held in place by wrought steel bolts. The removal of these manhole plates gives access to every tube in the boiler, and the drums are large enough to enable a man to work inside conveniently. The water is fed into the rear upper drum, and flows through the various tubes to the mud drum beneath, coming in contact in its descent with the ascending gases and becoming heated sufficiently to cause the precipitation of magnesia, lime and other salts contained in the water and that separate from it at the higher temperatures. All these precipitates collect in the mud drum. As a result the two forward rows of tubes are filled with comparatively pure water and danger of scaling is therefore, to a large extent, avoided; in fact, one of the principal claims made for the Stirling boiler is its ability to successfully handle very impure water. Further than this there remains little to be said, the sectional perspective view, shown on the opposite page, helping to make the main features of the design quite clear.

(*To be continued.*)

COLLECTION OF DUST IN WORKSHOPS.*

By R. Kohfahl.

TWO patents relating to a dust collector for flour mills were granted to Mr. F. Prinz on February 20, 1883, by the United States Patent Office. A company was organized in Milwaukee which pushed the manufacture of the new machine with energy, and it was soon widely spread over those establishments of the country for which it was destined.

The modern flour-mills of the United States, following the example given by Hungary, had already succeeded at that time in producing a flour of very high standard by carefully cleaning and gradually reducing the wheat, and by amply purifying the middlings won by the breaks. In the cleaning and purifying process, machines were used in which the loosened particles of dust and bran were separated from the grains and the middlings by a current of air. The dust or bran-laden air was then conducted into large dust-chambers, to reduce the velocity of the air to such a degree that the dust or the bran could fall down on the floor of the dust-room while the air would pass out through openings in the walls or in the roof. These dust-rooms only answered their purpose in a very imperfect manner; they occupied a large space, required long air-pipes, and increased the danger to the mill from fire.

The Prinz dust-collector afforded a perfect filtration of the dust-laden air close to the places where it was produced. The cleaned air could be allowed to re-enter the room from which it was taken, while the more or less valuable dust or bran was continually collected, and therefore ready for any further process. These advantages offered by the new machine were of such quality that it was rapidly introduced into most of the flour-mills of the country.

From the United States the Prinz dust-collector was exported to England and Germany. While in England, as in America, the flour-mills especially made use of the new machine, a greater field of application seemed to open for it in Germany. In this country, the annoyance and injury from the dust, from which the workmen had to suffer in many industrial manufactories, were felt the more deeply since the government constantly took pains to improve the lot of the working populace by special laws and by keeping the manufactories under the continual control of the state. Many engineers, therefore, were engaged in the problem of removing dust. It is comparatively easy to suck up the dust by a pipe emptied by an exhauster at all the places where it is whirled up either by action of the hand or by moving machinery. But then the dust-laden air which is blown out of the fan has to be filtered in order to recover the dust. In most cases the dust is worth money, and this reason would suffice to cause an attempt to recover it; but even if the loss could be endured, it would not be convenient to blow the dust outside of the building. This could only be allowed in exceptional cases; for instance, where a factory lies quite isolated in the open country.

In Germany, therefore, a very good chance was given for the application of dust-collectors, and in conse-

* From a paper presented at the International Engineering Congress at Chicago.

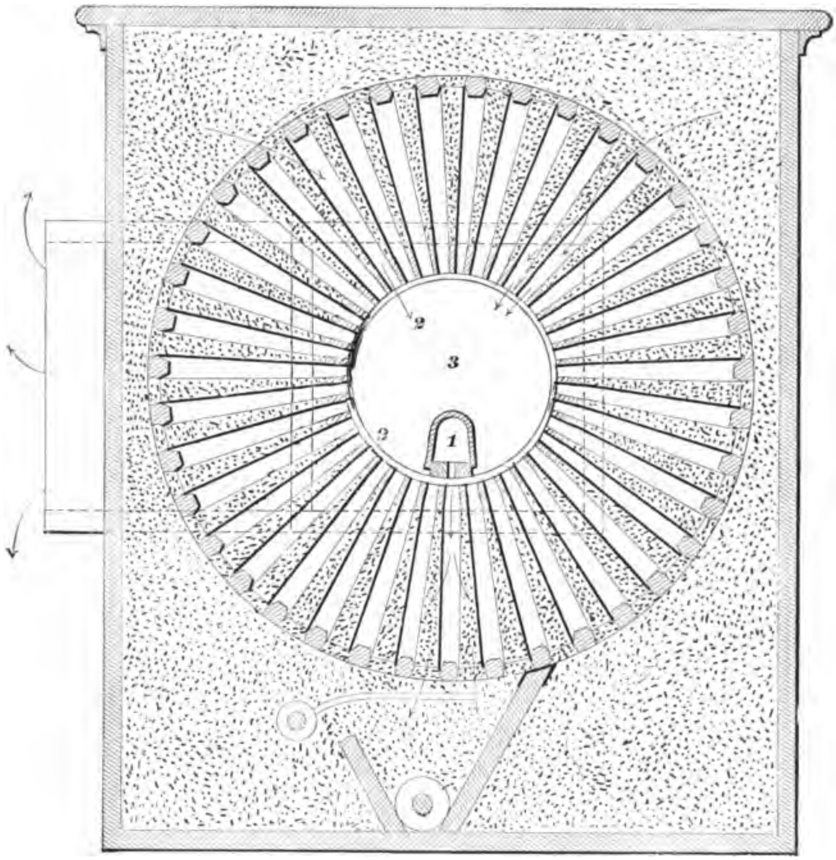


FIG. 1.—VERTICAL SECTION OF THE PRINZ DUST COLLECTOR.

quence many new constructions were brought upon the market. It became evident, however, very soon that different kinds of dust also required different handling. The very fine dust, for instance, in mills for Portland cement, for phosphate, for slag, or for chalk, is far more difficult in treatment than the dust of flour-mills, which for the greatest part is composed of the coarser particles of bran.

Such more difficult problems of dust removing the Prinz collector has not quite been able to master, nor have the competing apparatuses given more satisfaction. To create a machine suitable also for the more difficult cases, it became necessary to find out the reasons for the failure of the knonw constructions, and then to invent a new one which would be free from the faults of the former. It is to a form of dust-collector which has stood the test of the most difficult problems of dust-removing, and which really may be called a universal apparatus, that the author desires to call attention. Before, however, describing this dust-collector, the author will try to explain the reasons of the limited applicability of the Prinz collector. Assuming as well known the construction and operation of this machine, two sections of which are given in Figs. 1 and 2, the author expresses his belief that the said reasons are to be found in—

1. The rotating cage ;
2. The arrangement of the filtering cells around a horizontal axis.

The strain of the ribs forming the cage or balloon changes at every rotation of the latter, and this circumstance must at last damage the coherence of the cage. The exact working of the apparatus, and especially of the back-draught of air, depends upon the air-tight contact of the tube 1 with the inner ribs 2 of the cage. If these ribs cease to form an accurate cylinder the close contact is destroyed, and then more or less of the back-draught of air entering the tube 1 will be lost by leakage.

As to the arrangement of the filtering-cells around a horizontal axis, attention may be called to Fig. 1, where all dust-filled space is punctuated. If the air in the apparatus is at rest for some time, every particle of dust will sink down under the influence of gravity until it hits on a solid wall. It will be seen that only from between three or five of the lower cells the dust can fall down unhindered into the bottom of the casing.. Between all the other cells, however, the falling dust will be stopped by the walls of the cells and will rest on the filtering cloth ; moreover, in the cells of the upper part of the balloon dust will enter from outside of it. Of course, gravity will act in the dust-collector, when set at work, exactly in

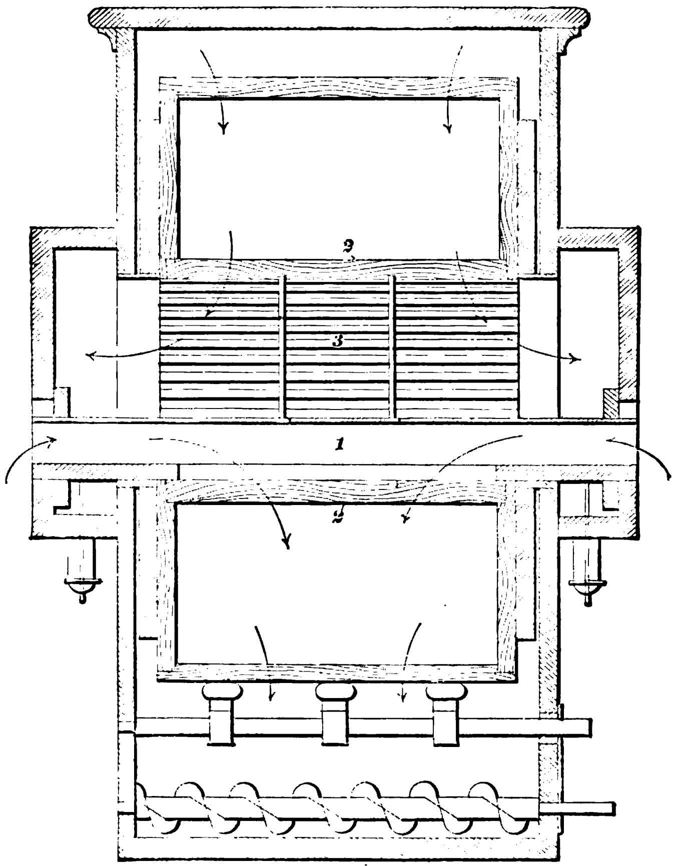


FIG. 2.—SECTION OF THE PRINZ DUST COLLECTOR.

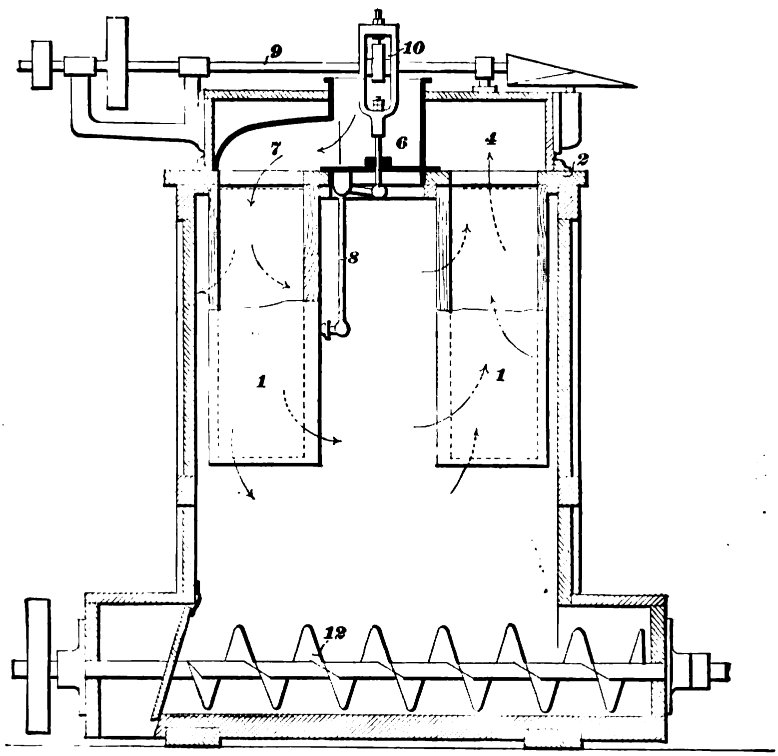


FIG. 3.—VERTICAL SECTION OF THE NAGEL & KAEMP DUST COLLECTOR.

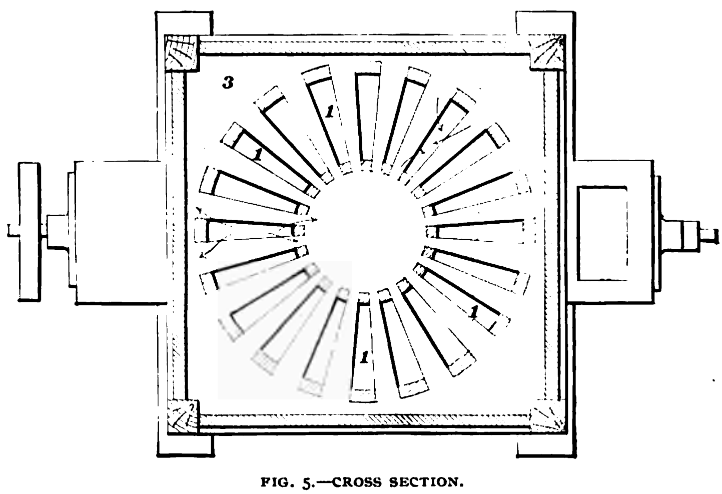


FIG. 5.—CROSS SECTION.

the same manner. The dust-laden air being drawn radially in between all the cells, gravity will diminish the obstruction of the flannel through the air-draught only at the few lowest cells, while at all the other cells it will increase the obstruction; and this increasing action will last for every cell until it has become again one of the lowest by the turning of the cage, i. e., by far the

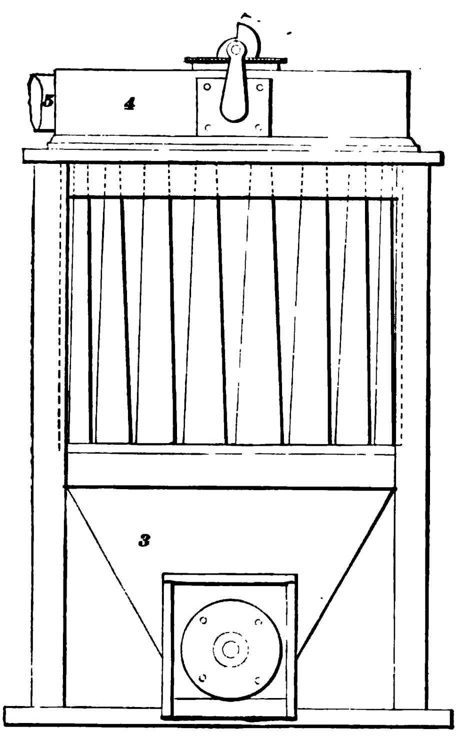


FIG. 4.—END ELEVATION OF THE NAGEL & KAEMP DUST COLLECTOR.

greatest part of the time. Therefore the arrangement of the cells around a horizontal axis must be called an inappropriate one.

In the dust-collector here to be described,* which also uses a back-draught of air for the cleaning of the cloth, the said disadvantages are totally avoided. The cloth-covered filtering-cells 1 are screwed into a strong horizontal plate 2, the openings of which, shown in Fig. 6, correspond exactly with the open upper ends of the cells 1. The plate 2 divides the lower part 3 of the chest from the upper part 4 of the same. The upper compartment 4 is connected by the pipe 5 with a suction-fan, and within it is placed a rotating hollow cylinder 6, closed at the bottom and open at the top and extending through the upper horizontal wall of the compartment 4. From the said cylinder branches off a hollow arm 7, having at its lower side an opening adapted to register with one of the cells, the flanged edges of the said opening being in sliding contact with the partition wall 2. To the cylinder 6 a hammer 8 in the shape of a bent lever, is fixed, which is operated from the shaft 9 by a cam and the rod 10. The cylinder 6 is provided with teeth, the number of which is equal to the number of cells; it is rotated by a pawl 11, in such manner that the hollow arm 7 will always come to rest for a short time exactly over one of the cells. A creeper 12, discharges continually the dust collecting in the chest.

The dust-laden air enters into the lower part of the chest by a pipe extending preferably into the cylindrical inner part of the cage. It then spreads radially between the cells and the lower part of the chest, and is filtered through the vertical flannel walls. As the exhauster blowing off the cleaned air leaves the upper compartment 4, and indirectly also the lower compartment 3, fresh air from the surrounding room will, on account of its higher pressure, flow through the cylinder 6 and the hollow arm 7 into that single cell just covered by the said arm and pass through the cloth of this cell into the compartment 3. At the same time, the hammer 8 imparts several blows to the same cell, the cloth of which is thus perfectly cleaned by the combined action of the back-draught of air and the blows of the hammer. The arrows in the Figs. 3, 5 and 7 indicate the movement of the air. It will be seen that in this dust-collector

First, the cage is fixed immovably to a solid and stationary plate; that,

* The machine which is shown in Figs. 3 to 7 was granted the United States Patent No. 361,711 on April 26, 1887.

Secondly, the instrument for introducing the back-draught of air rests and slides on this stationary plate, and therefore can be kept easily and constantly in air-tight contact ; that,

Thirdly, all the filtering cells being arranged vertically, the dust can fall down unstopped from any point between the cells as well as from outside of them ; and that,

Fourthly, gravity at each point diminishes the obstructing action of the dust-laden air, but increases the cleaning action of the back draught.

These advantages account for the great superiority of the dust-collector hot gas, iron is used also in this place, while at the same time the cloth is so impregnated as to become fireproof. The chest is provided with large doors on each side through which the cage can be brought in conveniently. The cage itself is composed of four quadrants, from which each cell can be easily detached, thus facilitating the changing or repairing of single cells. The distance from one cell to the other is wider than usual in order to prevent the choking of the intermediate spaces, and is particularly wide in dust-collectors for cotton mills, the dust of which is fibrous and inclines to cohere.

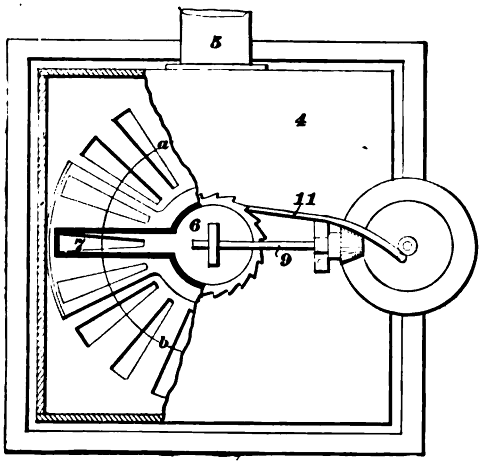


FIG. 6.—TOP VIEW AND SECTION.

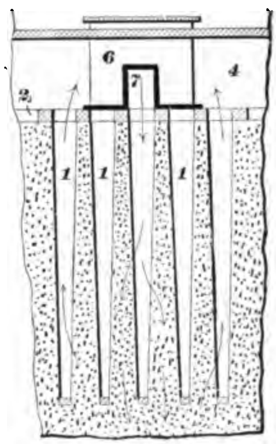


FIG. 7.—SECTION ALONG a b OF FIG. 6.

herein described over the competing machines as proved by practical experience. The former reaches the same capacity with far less amount of filtering surface, and with the same surface does a great deal more work. The machine is at the present time built in four sizes, with wooden or iron chest, with or without an exhauster, with or without a mechanism for the automatical discharge of the dust, the latter being a creeper for the smaller sizes and a hopper-boy for the larger. The ribs of the cage are always made of wood on account of a more convenient fastening of the cloth ; only in such exceptional cases as for the filtration of

Each dust-collector is also furnished with a vacuum gauge, indicating the difference of the pressures of the air in front of the cloth and behind it. If the machine is started in the right way and not overcharged, the indication of this vacuum-gauge does not change at work. This could only happen if by any sudden overcharging of the collector the clogging of the cloth should be increased above the normal. It is, therefore, possible to convince one's self of the normal condition of the filtering surfaces without opening the doors of the chest, by only glancing at the vacuum-gauge. This renders the control of the machine at work very easy.

A few words may be devoted, finally, to the theory of the apparatus. Suppose p_0 to be the atmospheric pressure, p_3 the pressure of air in the lower compartment 3, and p_4 that in the upper compartment 4; the dust will be pressed against the cloth with the pressure $p_3—p_4$, and will be blown off from it with the pressure $p_0—p_3$. Each cell being subjected to the obstruction by dust for a far greater time than to the cleaning back-draught, the pressure $p_0—p_3$ must evidently be larger, mostly exceedingly larger than the pressure $p_3—p_4$. The difference of these two pressures must be the greater the more difficult the handling of the dust to be operated proves. The experiments made with the Nagel & Kaemp dust-collector have taught that for the proportion $p_0—p_3 : p_3—p_4$, the figures 2 to 3 will suffice for the most easily operated kind of dust; as, for instance, the light bran from middlings-purifiers, while it must be raised to the value five to ten for other kinds of dust, or even to fifteen to twenty in the most difficult cases. The means for adjusting the said proportion exactly to that value, which experience has taught to be necessary for a certain kind of dust in order to keep the cloth clean, exist in the correct regulating of the quantity of dust-laden air offered to the collector. This quantity may be greater for coarse, heavy or flat dust, and must be diminished for fine, light or globular dust. Of course, it is a matter of experience what quantity of dust-laden air the collector may be charged with, and, consequently, what cross-section must be given to the suction-pipe in each special case. The experiences gathered in this respect with the Nagel & Kaemp dust-collector extend very far, as the machine has been tried and is now constantly working with excellent success in the following branches of industry: Flour mills, pearling mills, rice mills, grain elevators, cement manufactories, cotton mills, paper manufactories, potteries; mills for chalk, for Thomas-slag, for granulated slag, for phosphates and artificial dung; manufactories of soda, of oil, of conserves, of chocolate, for peeling coffee; jute manufactories, cotton mills, paper manufactories, works for cleaning carpets or feathers, mills for sulphur, for tartar, for sugar and for chinchona bark.

THE LIFE AND INVENTIONS OF EDISON.*

By A. and W. K. L. Dickson.

Tenth Paper.

THE new Edison incandescent lamp of 1881, while falling short of its present perfection, was sufficiently advanced to admit of an extensive display at the Paris Electrical Exposition, on which occasion he was the recipient of five gold medals and a diploma of honor, the highest distinction conferred upon any exhibitor. The following cable was received by Edison from the official headquarters of the Exposition.

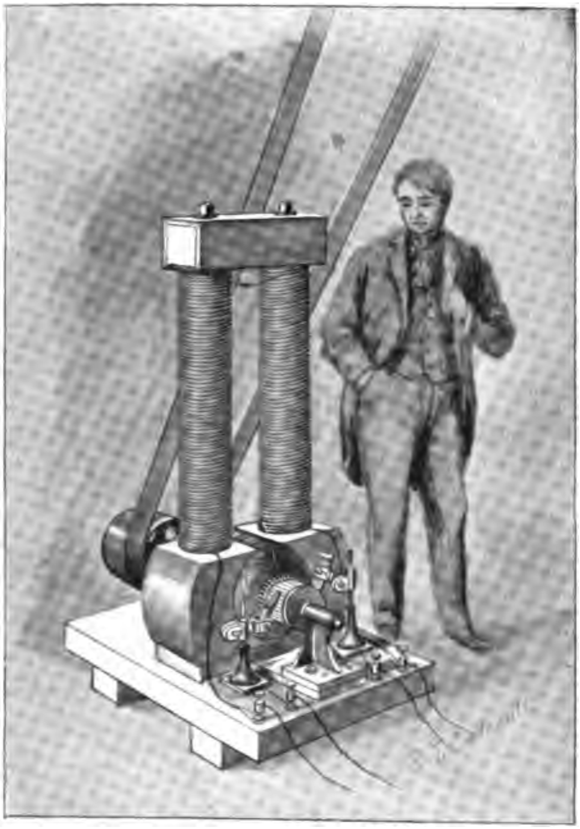
"Official list, published to-day, shows you in the highest class of inventors. No other exhibitor of Electric Light in that class. Swan, Fox and Maxim receive medals in class below. The sub-juries have voted you five gold medals, but General Congress promoted you to the diploma of honor. This is complete success, the congress having nothing higher to give."

Professor Barker, of the University of Pennsylvania, who was present at the Exposition, telegraphed Edison in the following terms: "Accept my congratulations; you have distanced all competitors, and obtained a diploma of honor, the highest award given in the Exposition. No person in any class in which you were an exhibitor received a like award." The third telegram sent Edison on this occasion was perhaps the most interesting, as reflecting the magnanimity and cordial appreciation of a rival competitor. Swan, the proprietor of the Swan incandescent light of England, cabled as follows: "You have received the highest award the jury has to give. I congratulate you." "Nothing succeeds like success," and the new system spread like wild-fire. The distinctions conferred by the Paris Exposition were only the prelude to many public recognitions of Edison's pre-eminence.

Among the different systems, employed in the Crystal Palace Electrical Exposition of London, on the following year, Edison's attracted universal attention. Its happy blending of mellowness and strength, like the soft brilliancy of Andalusian eyes, lent itself to the most varied effects. From the glittering coronal of frozen loveliness,—meet diadem for the Scandinavian Frost giants,—which overhung the concert-room of the Palace, to the tinted fires which leapt in the heart of fountain, flower and sward, the eye was intoxicated with beauty. The entertainment court was canopied with a chandelier of the most exquisite design, the work of Messrs. Verity & Co., gathering into itself the floral magnificence of a hundred favored climes. Metal and colored glass combined in the reproduction of nature's softest and richest hues, and a tiny spark, concealed among the petals, or nestling beneath the folded leaves, brought into relief each delicate curve and vein. Three hundred and fifty of these fairy blossoms were represented, ranging from the sunflower, the narcissus, the tiger-lily and the orchid, down to the modest clove pink, the whole enshrined in a basket of hammered brass. Ninety-nine Edison lamps, in three circuits, were employed, the brass stems of the flowers being hollow, so as to admit of the passage of the wires. A

* Began in November issue.

SOME REPRESENTATIVE NATIVE WOMEN, PHOTOGRAPHED BY MR. RICALTON IN HIS SEARCH FOR FIBRE,



AN EARLY EDISON DYNAMO, 1880.

miniature model of this chandelier, or electrolier, as our newly revised dictionary hath it, was presented by Mr. Edison to the Prince and Princess of Wales. It bore the following inscription, "A Souvenir of the visit of their Royal Highnesses, the Prince and Princess of Wales, to the Electrical Exposition of the Crystal Palace, 1882, with the compliments of Thomas Alva Edison." Electricity was stored within the recesses of the bouquet, so as to be instantaneously brought into play or extinguished.

What more superb tribute was ever laid at the feet of Denmark's Rose? Ah! potent wizard, you shame the records of the Arabian nights, and the fabled glories of the East. We must look from these to the pictured paradises of the blest, where the gems are lit by deathless fires, and where fountains and foliage give forth Eternal harmonies.

The Edison exhibition was not limited to these decorative effects, but brought into view every domestic exigency to which this luxury-loving century has given birth. The plasticity of the Edison incandescent system, the steady, potent and mellow radiance of the lamp, and its exemption from the splutter and glare which characterized the other methods, excited universal comment, and elicited even from the cautious and conservative British press the tribute of an unwilling admiration.

"The palm is undoubtedly carried off by the Edison show, which is extremely beautiful," remarked one pe-

riodical. "Mr. Edison's splendid show in the Concert Room and Entertainment Hall continues to attract more attention than any other,"—observed a second. The Illustrated London News commented feelingly on the soft, delicious radiance diffused by the Edison lamp, and admitted that its soothing influence had totally neutralized the popular objection to electricity for internal illumination. It concluded by emphatically pronouncing the Edison exhibit to be "unique and well meriting the encomiums bestowed upon it." Equally important and conclusive results were achieved in succeeding Exhibitions, notably those held at Munich in 1882, at Vienna in 1883, Philadelphia in 1884, Paris in 1889, and at Minneapolis in 1890.

Electric lighting formed a prominent feature of Edison's exhibit in the Paris Exposition of 1889. Nine thousand feet were aliotted the inventor, in view of the unusual magnitude of his contributions to experimental science, and this space was filled to overflowing with the varied fruitage of Edison's ripened thought. In the centre of this unique display was an enormous model of an incandescent lamp, forty feet high, the globe constructed of no less than twenty thousand incandescent lamp bulbs, so brilliant as to illuminate the entire expanse of the main building. On either side of this concentrated effulgence were ranged the French and American flags, composed of colored incandescent lamp bulbs, the jewelled effect of which recalled the glories of Aladdin's magical cave, or the fabled wealth of Sinbad's valley of gems.

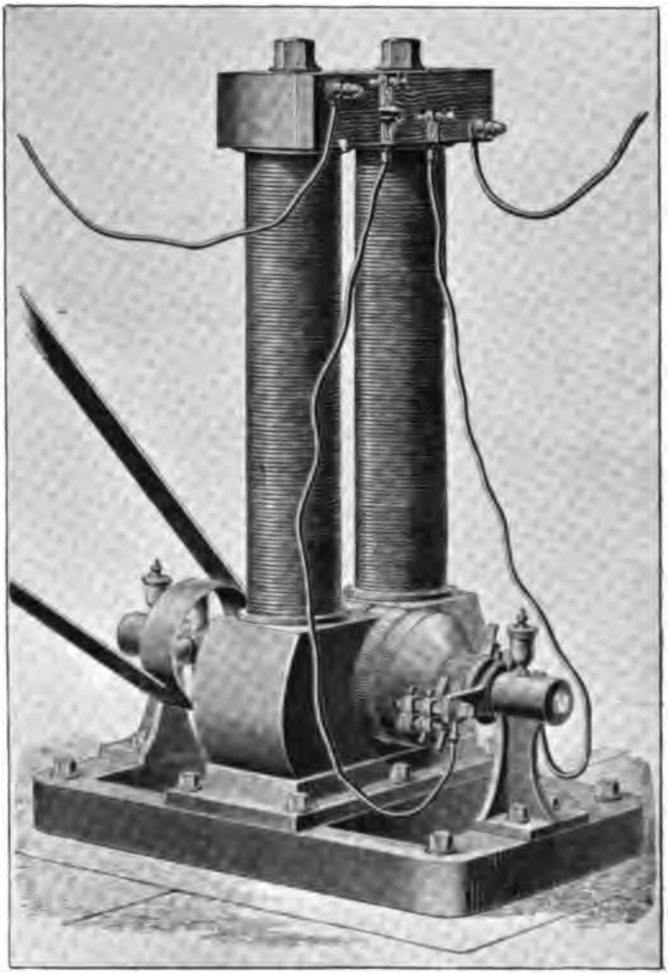
THE FIRST INCANDESCENT CENTRAL STATION IN THE WORLD—APPLETON, WISCONSIN, 1882.—ONE DYNAMO, FIFTY LIGHTS.

A dynamo of enormous proportions, the ripened outcome of over ten years

THE EDISON LAMP WORKS AT MENLO PARK IN 1880.

of experimental work in electrical generators, occupied a central position among this luminous efflorescence, like Vulcan among the Loves. In the construction of this and kindred machines, Edison has employed massive field magnets, in place of the extremely light ones, utilized in the immature stages of electrical illumination, thus securing an efficiency undreamt of by his predecessors. In a series of charts, suspended against the walls, might be traced the wonderful evolution of this machine, from the first rude generator, consisting of an electric magnet, before which a gigantic tuning fork was made to vibrate, through the gathering perfections of later forms, heralded by that, known as type Z, of twenty-five candle-power, the source of current for the seven hundred lamps which sprang into simultaneous birth in the buildings of Menlo Park. This class of machine is shunt wound, the magnet spool cores being considerably longer than those in present use. In succeeding diagrams, the gradual increase of the number of magnet cores in parallel is shown, commencing with four-spool cores, and extending to six-magnet cores in parallel. At this point the inordinate length of the magnets, and the undesirability of grouping together so many parallel windings forced themselves on Edison's attention, and led to the curtailment of their length, and the increase of their sectional surface, features embodied in the perfected dynamos of the day.

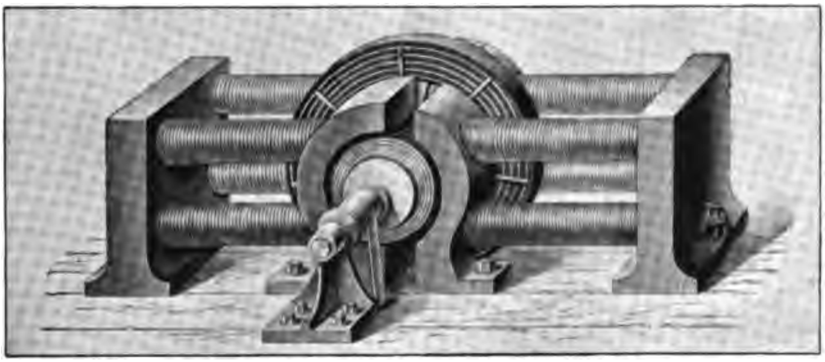
Prominent in this graduated series of electrical generators was the famous "Jumbo" dynamo, constructed in 1881, first seen at the Paris Exhibition of that date, and afterward exhibited at London, Milan, and New York, where its daring innovations on the accepted groove of ancient methods were already sufficiently startling to excite a strong wave of popular wonder. An allegorical picture was also displayed,



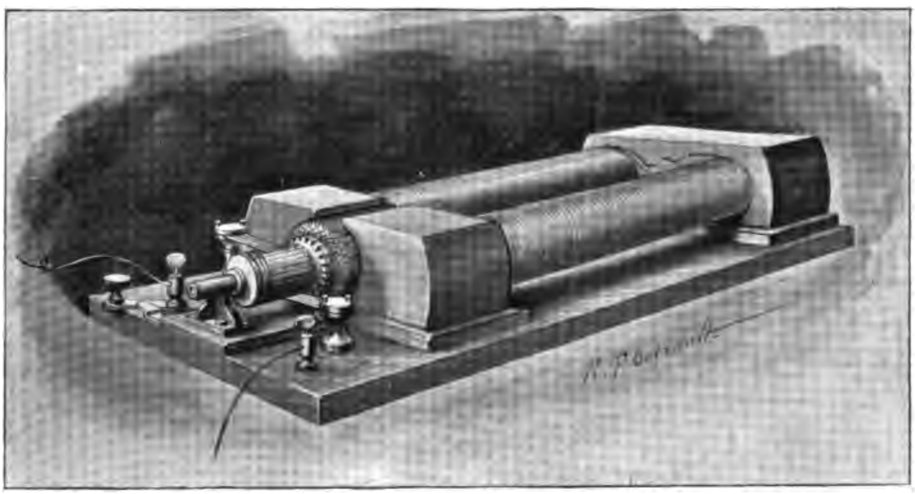
AN EARLY EDISON DYNAMO, 1880.

entitled "Menlo Park, the birth place of the Incandescent Lamp," and a series of charts was exhibited, representing the more prominent buildings of the world which have adopted the Edison methods of lighting, together with illustrated statements of the nature and extent of Edison's methods for disseminating light and power. These, at the time of the Paris Exposition, demanded no less than seven hundred miles of underground conductors in the United States alone. The Exhibition also embraced every auxiliary appliance utilized in the production of the electric light, such, for instance, as the Edison meter, the outcome of careful experiments in connection with all varieties of clock work, motors, electro-magnets and springs, heat, electrolysis and electro deposition, and designed to register the amount of current furnished to consumers. The undeviating accuracy of this contrivance stands out in bold relief against the erratic and unprincipled records of the gas meter, and housekeepers, whose amiable credulity has been abused by that justly

infamous institution, may again foster a modified belief in the integrity of their species.

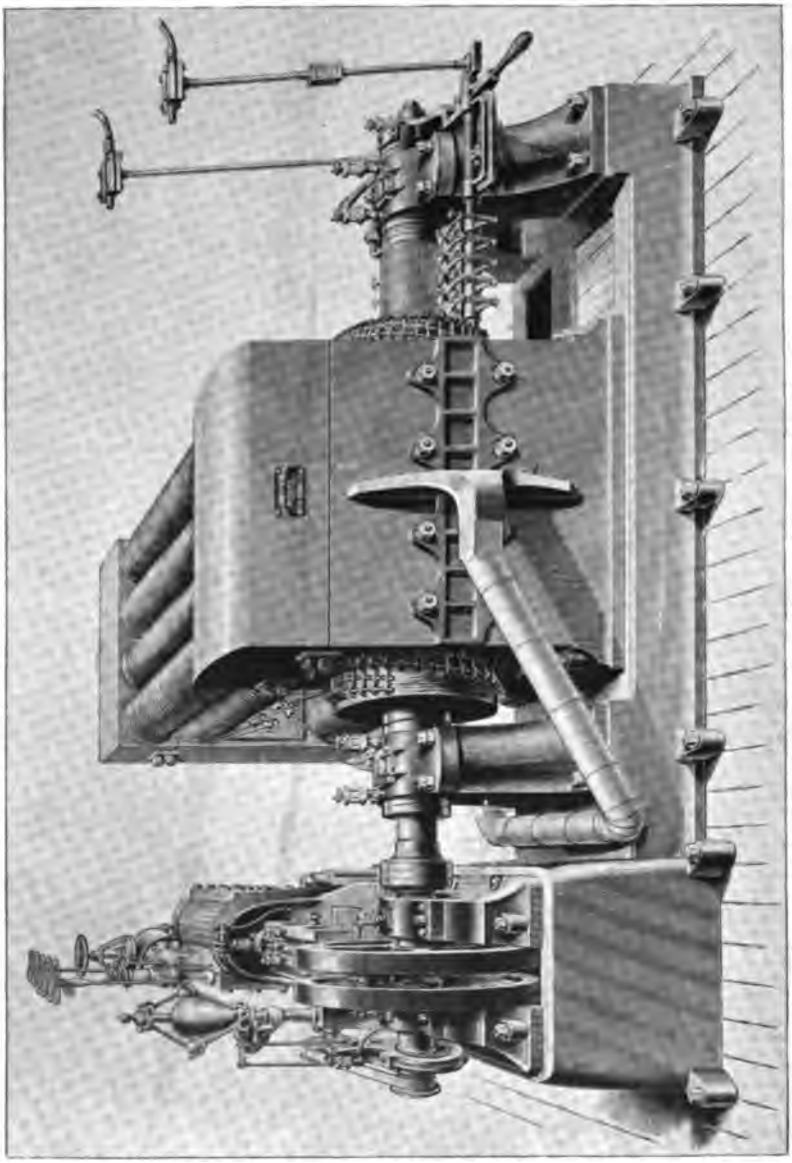


PLATING DYNAMO.



EARLY TYPES OF HORIZONTAL DYNAMOS OR MOTORS, 1881.

Under the fostering auspices afforded by these public expositions the Edison incandescent light became extensively introduced, in connection with public squares, buildings, etc. The commercial strides of the new industry were no longer to be impeded by the feeble barriers of international prejudice, and England, yielding to the infectious example of her sister powers, repealed in 1888 the Parliamentary law enacted in 1880, providing that all electric light plants should, at the expiration of twenty years, pass into the possession of the Government. To the crippling effect of this edict had been largely due the stagnation of electrical industry in Great Britain, but the remedial measures were attended by an instantaneous revival of interest, and to-day there is not a hamlet in England, however insignificant, which is not in vital connection with the central sources of supply. Long before the tardy concessions of the Isles, electricity had established her brilliant sway amongst the dim regions of romance. The soft gloom of Oriental bazaars, with their perfumed and mysterious recesses, the sculptured avenues

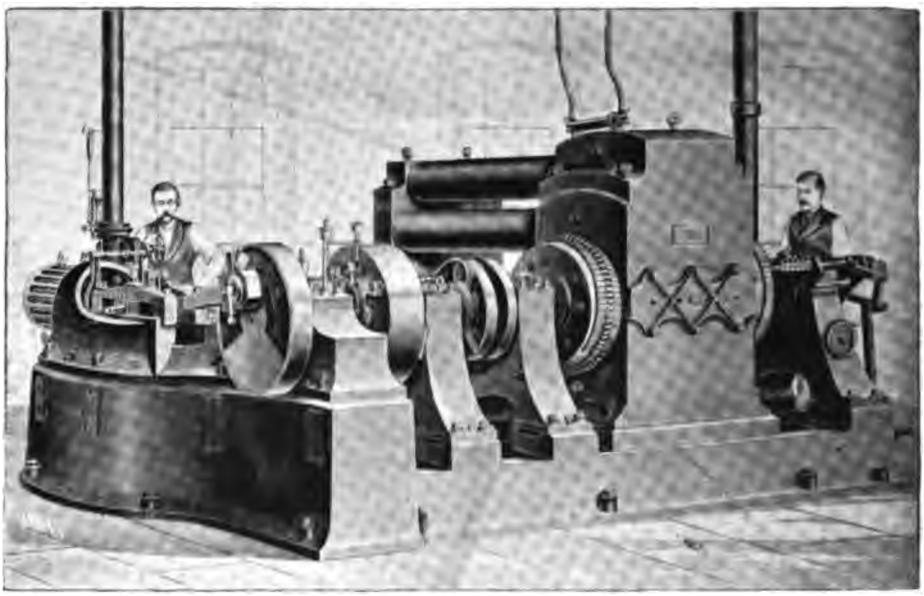


THE EDISON JUMBO DYNAMO, 1881.

of colossal temples; the quaint strongholds of mediævalism; the primitive structures of rude and uncultured races; these were brought under the new dominion, and despoiled of such lingering fragments of mystery as had been spared by the march of time. Nor were the new laws exemplified on the surface of the earth alone. The Edison incandescent lamp lent itself with peculiar felicity to the work of miners and divers, being potent, steadfast and innocuous,—three indispensable attributes, when we consider the density and gloom of the atmosphere, the delicate nature of the operations and the perilous isolation from human help. Within the range of human vision came unguessed miracles of underground architecture, wrought by patient Niebelungen hands in the gloomy recesses of the world; gems of "purest ray serene" yielded their shrouded loveliness; palaces floated on the waters of bay and ocean, recalling the splendors of lost Atlantis, miracles of submarine life flashed into view, fretted spires of coral, rose-hued and ivory, beds of translucent and palpitating flora,

> "In the purple twilights under the sea.
>
> . . . .
>
> Broad sea wolds in the crimson shells,
> Diamond ledges that jut from the dells,
> Turkis and agate and almondine."

Stimulated by public appreciation, the Edison industries steadily gained in strength and magnitude. The European Company was organized in 1882, plants were established in important transatlantic centres, and the Edison London Company sprang into existence. On this side of the Atlantic, the commercial statistics were even more encouraging. The impetus originally given by the Menlo Park Exhibition had gathered momentum with each succeeding day, and the modest premises of the Edison Electric Light Company were no longer in keeping with the majesty of the ripening enterprise.



AN EDISON DIRECT CONNECTED GENERATOR, 1881.

(*To be continued.*)

SEMI-PORTABLE ENGINES IN ENGLAND.

By W. Fletcher, M. E.

TO give a list of the numerous examples of stationary engines manufactured in England would occupy considerable space without serving any useful purpose, but out of a formidable list the writer believes that a description of what is known as the under-type engine will be of interest. It is not necessary to name the many purposes to which the under-type engine is now applied, but it might be mentioned that it has supplanted a good many slow moving engines and cumbersome boilers with their costly brickwork setting, in mining operations as well as for driving electric lighting machinery.

Simplicity of design, as will be seen by reference to the illustrations, is one of the immediately striking features of the under-type engine, and with this is combined ease of access to all the details for adjustment and repairs. The rigid framing and great strength throughout render the engine peculiarly adapted for high speeds and, being self-contained, the weight of the boiler with the water in it insures steadiness, so that no expensive foundation is required, a few courses of brick being sufficient. No costly engine house nor high brick chimney is necessary. The engine can be easily removed in case of any alterations to the building plans, and in many instances this is a great consideration for temporary installations and for all experimental purposes, while for tenants or leaseholders these engines are preferred, because they can be quickly removed and as readily placed again ready for work. In fact, nowadays a saving in time required for the delivery and setting of engines is often of the greatest importance, so that the circumstance that in this style of engine time in setting up has been reduced to a minimum will be appreciated. The engine comes to its destination all but finished, and is erected and ready to work without delay. For transport it may be conveniently arranged so as to be packed in small compass. It is easily and economically worked, and, being so compact, it can be started, reversed or stopped in any position with precision. The levers for regulating these movements are conveniently arranged near the firehole, so that one man may be employed to drive the engine and do the stoking as well, if necessary. The engines are very economical in fuel, the cylinders are generally well steam-jacketed and drained, and the cylinders, valve chests and boilers alike are carefully covered with non-conducting substances, and afterwards cased with sheet steel.

In most cases the compound system is adopted, by means of which a further economy is effected with little, if any, increased complication. For compound engines the working pressure is about 150 pounds per square inch, and the steam is expanded to about eight times its original volume, being discharged at a little above atmospheric pressure. Some form of automatic expansion gear is usually applied which regulates the quantity of steam admitted into the high-pressure cylinder in proportion to the work done by the engine. The exhaust steam is conducted into the chimney for increasing the draught, enabling refuse substances or cheap coal to be used as fuel in the large firebox. The boiler very properly is only used for generating steam, having none of the engine parts attached to it or burdens

to bear, and it may be removed from the engine by simply breaking the steam pipe connection joint, and if need be another boiler could be temporarily placed beside the engine to supply it with steam.

The method of placing the engine beneath the barrel of a locomotive, multitubular boiler, now so largely adopted for stationary purposes, is not, however, by any means a modern idea. Several engineers at different periods have claimed the credit of being the inventors of this type of engine, but the name of the one entitled to the credit is unknown. More than forty years ago the engine and boiler of a small screw steamer used in Lancashire, England, were arranged exactly the same as the present form of underneath engine. It is not certain by whom this craft was built, neither is there any information as to the maker of the engine, but it is known that the steamer was running as far back as the year 1852.

Messrs. Manning, Wardle & Co., of Leeds, England, were the first to make a specialty of this type of engine for stationary purposes. Their first engine was turned out a little more than thirty years ago, and during the first ten or fifteen years of their career they built a large number of stationary engines of various sizes intended for all kinds of work. The engines were all similar in arrangement and design ; there may have been slight alterations in minor details at times, but the general features were the same in all that were built. One of these engines is at present working the machinery in one of the shops of the builders, and has been doing good work for about thirty years. The manufacture of all stationary engine work, however, was discontinued some years ago by this firm so as to enable them to devote their energies exclusively to the building of locomotives, for which they have acquired a wide reputation. Figs. 1 and 2 represent two views of the earliest engine of the under-type, built by this firm about 1860. The engine has a

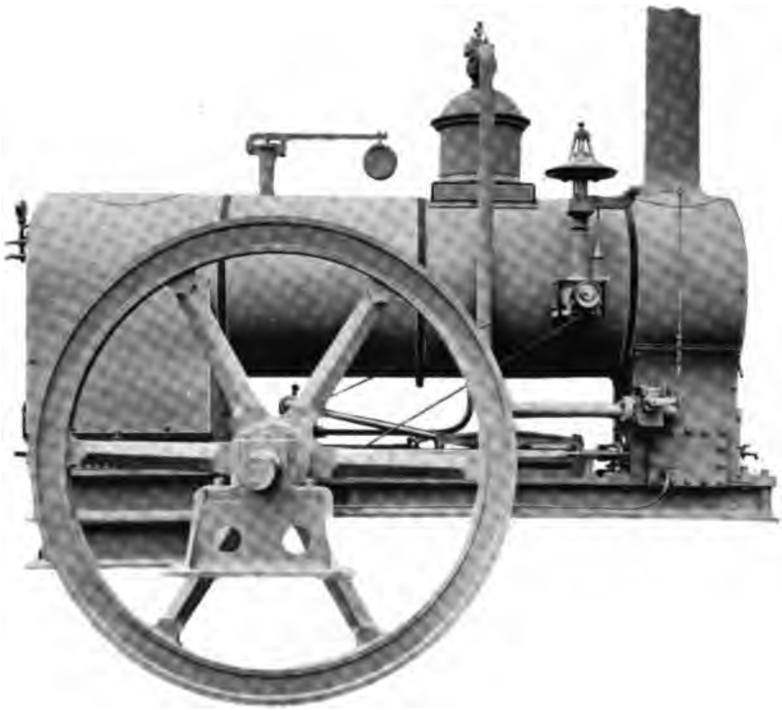


FIG. 1.—SINGLE CYLINDER UNDER-TYPE ENGINE.

single cylinder which is bolted down to a cast-iron base-plate. The upper part of the cylinder forms a chair for supporting the smokebox end of the locomotive boiler, while the opposite end of the foundation plate is arranged as an ash-pan for receiving the firebox end of the boiler. The governors are of the counter-weighted type, driven at a high speed, and control the engine by means of a throttle-valve, as shown. One end of the crank-shaft is supported by a bearing placed on the foundation plate, and the other end is carried on a raised sole-plate. The long stroke feed-pump is driven by a pin secured to the guide-block. The cylinder and boiler are carefully coated with non-conducting composition, and then covered with sheet-iron. A dome is provided on the boiler. The engine is creditably designed, and presents several features worthy of notice. It is specially interesting, because it represents the earliest practice in this line, and by means of it the reader will be able to gauge the progress that has been made in the design and construction of these engines since their first appearance.

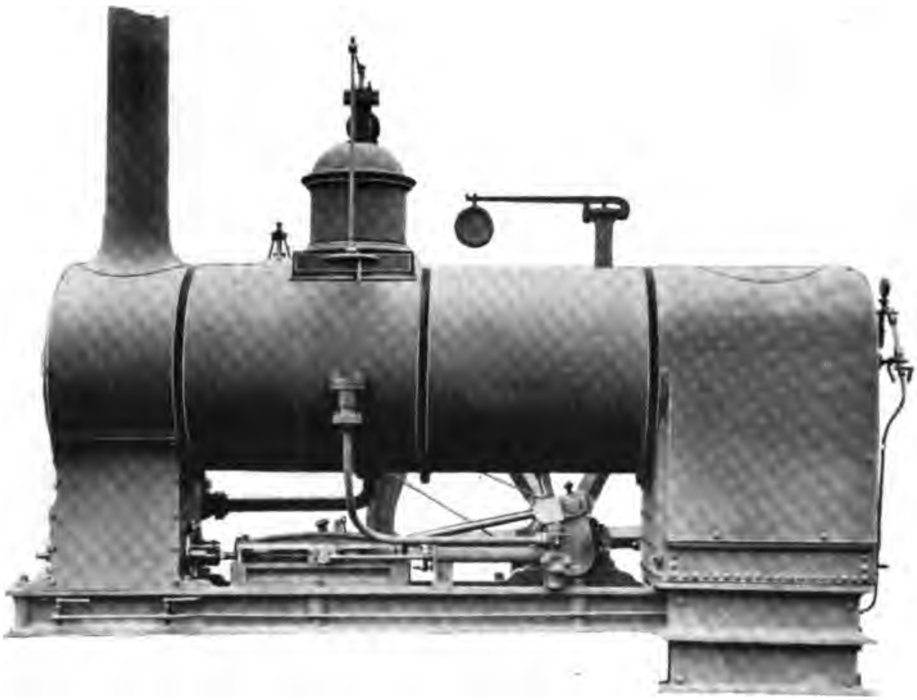


FIG. 2.—SINGLE CYLINDER UNDER-TYPE ENGINE.

In England there are more than a dozen firms who manufacture under-type stationary engines, and while in general arrangement these engines are somewhat similar to one another, they are as diversified as possible in points of detail. The engines made by one or two of the leading firms are models of neatness of design and solidity of construction. A symmetrical arrangement of the parts has been aimed at with satisfactory results, causing the engines to present a graceful and pleasing appearance. Some engines of this class which are turned out strike one, it is true, as simply makeshifts, made to pass muster by a liberal supply of paint and other subterfuges to make up for the lack of good workmanship. A poor example of this type of engine should not, therefore, be taken for the purpose of forming an opinion of them all. At the present time single and double cylinder under-type engines are made to be worked at 100 pounds pressure

of steam, as well as compound and triple-expansion, condensing or non-condensing designs, suitable for a working pressure of 150 pounds per square inch. The cross-compound engine is the one most in demand, more being made on this system than on any other. It must be added that the largest sizes are often fitted with surface or jet condensers, so that there is every reason to look for economical performances.

Outline views of a modern compound under-type engine are given in Figs. 3 and 4. The high and low-pressure cylinders, valve-chests, stop-valve chamber and cradle for supporting the smoke-box end of the boiler are combined in one casting, which is suitably formed for bolting between two wrought-iron girders. Both the cylinders are steam-jacketed with steam direct from the boiler, and well drained by means of an automatic steam trap placed beneath the floor. The working barrels or liners are made of a special mixture of hard iron or steel, and are forced into the cylinder casing by hydraulic pressure, the annular spaces between the liners and the casing forming the jackets. In order to reduce the complication of the cylinder casting, the intermediate receiver is formed separately, in a U-shaped casting, and bolted beneath the cylinders as shown in Figure 4. Free access can be had to the slide valves by the removal of the valve chest covers, which are placed outside, and the stop valve can also be examined by taking off a small lid. The cylinder and steam chest covers are provided with forcing off screws. In many steam engines these screws are thoughtlessly omitted, and when it is desired to remove the covers, use must be made of iron wedges. An auxiliary valve is provided for admitting high-pressure steam to the low-pressure cylinder, and both cylinders have separate and independent exhaust pipes, so that the exhaust from the high-pressure cylinder may pass direct into the stack, thus relieving that cylinder of back-pressure. Both the cylinders then work with high-pressure steam, but the auxiliary valve regulates the supply of steam to the low-pressure piston, so that equal power is developed

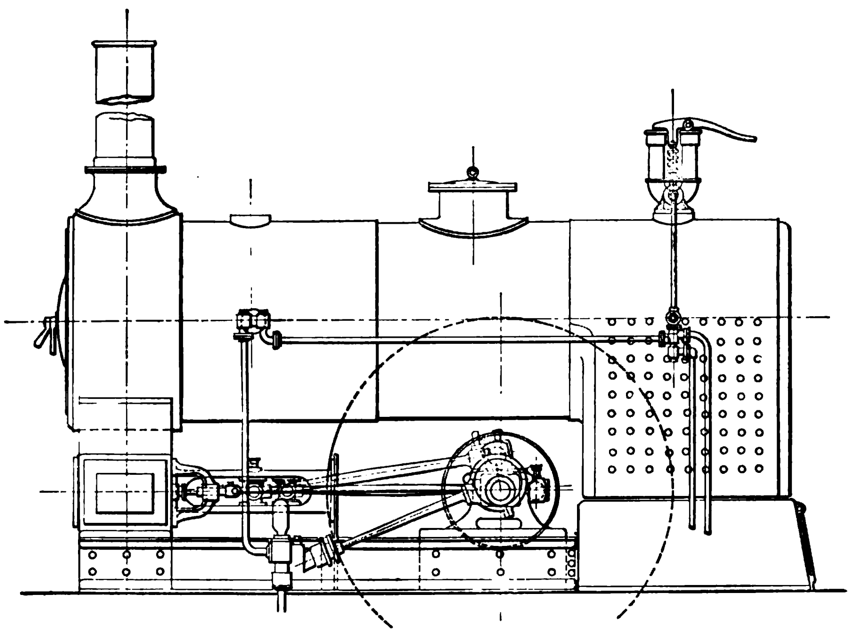


FIG. 3.—SIDE ELEVATION OF A COMPOUND UNDER-TYPE ENGINE.

in the two cylinders. The object of this arrangement is to give increased power to the engine when starting under a load. All the cocks, levers and pipes are fitted to the outside of the cylinders, rendering them easy of access for adjustment. In order to facilitate the application of a feed water heater, or a condenser, as the case may require, two exhaust outlets are provided, one on the end of the cylinder above the low-pressure cover, and another inside the smoke-box for conducting the exhaust into the chimney when neither of these appliances are needed. For working the air pump the low-pressure piston rod is made to pass through the back cylinder cover. The high-pressure cylinder is fitted with a sight feed lubricator, while the low-pressure cylinder has a displacement oil cup. Special attention is paid to the lagging of the cylinders, which are generally coated with non-conducting composition, and covered with cold rolled sheet steel.

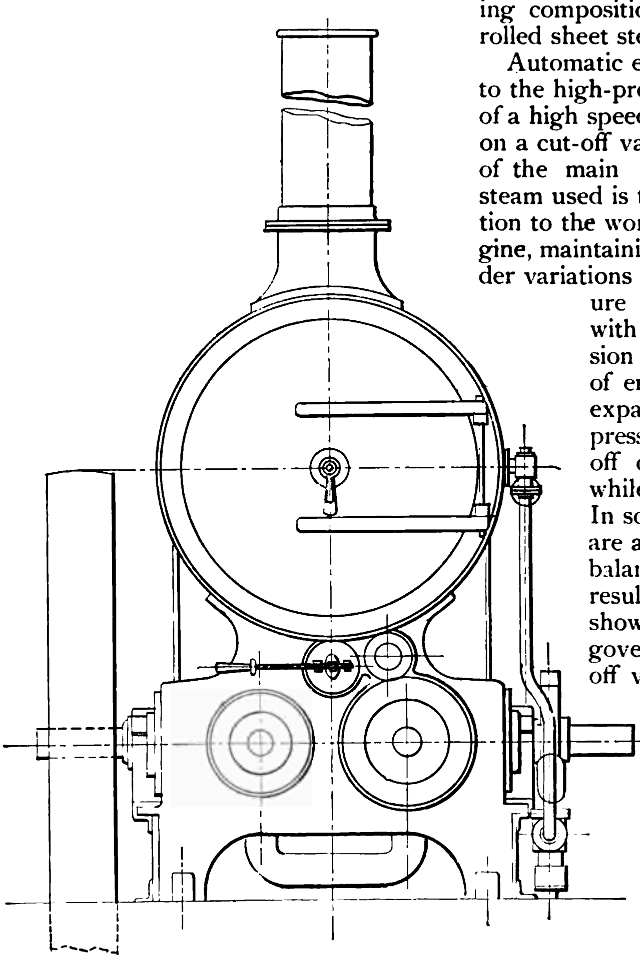


FIG. 4.—END ELEVATION OF A COMPOUND UNDER-TYPE ENGINE.

Automatic expansion gear is applied to the high-pressure cylinder, consisting of a high speed governor acting directly on a cut-off valve, working on the back of the main valve. The quantity of steam used is thus regulated in proportion to the work required from the engine, maintaining uniformity of speed under variations of load. The low-pressure cylinder is also provided with a simple type of expansion gear. In the larger sizes of engines, Meyer's system of expansion is used for the low-pressure cylinder, and the cut-off can be varied by hand while the engine is running. In some cases shaft governors are applied in conjunction with balanced slide valves with good results; thus, the engine shown in Fig. 3 has a shaft governor regulating the cut-off valve of the high-pressure cylinder.

Cylindrical bored guides are now adopted in place of the ordinary guide bars, one end forming the cylinder cover and stuffing box for the piston rod gland, while the other end is bolted to a bridge plate, the latter serving to connect the side frames together in the centre of their length. The original engines were always mounted upon cast iron bed plates. The illustration shows the usual channel iron frames which have some advantages for export, but these wrought iron frames appear to be giving place to the cast iron bases; indeed, some makers

have never departed from the cast iron foundation plates.

The crankshaft is usually formed of steel, bent under the hydraulic press; the dips are of the same shape as forged slab cranks, but, being bent, the delay and labor of drilling and slotting of slab cranks is avoided, while the fibre of the material is continuous throughout the piece.* In some cases the cranks are counter-balanced. To obtain the requisite stiffness, the crankshaft bearings are in one casting which extends across the engine and is bolted between the two channel frames, making a substantial connection at this end of the engine, while the bottom of the bracket is suitably shaped to form an oil catcher. The firebox of the boiler rests on a deep ashpan which is bolted to the end of the girders, and the damper doors are sufficiently large to admit a man in case any repairs are required inside the firebox. In addition to the ordinary pump, it is usual to equip these engines with an injector or a donkey pump as an auxiliary feed supply. The boiler is of the flush top type, lagged from end to end. All the flanging and riveting is done by hydraulic pressure, and the boiler is designed to work with 150 pounds pressure. The steam and exhaust pipes are arranged in the smoke-box in such a manner as not to interfere with the sweeping of the smoke tubes.

Numerous tests have from time to time been carried out by the makers of high class, compound, non-condensing under-type engines, and the average coal consumption of the various engines when working under favorable conditions has not exceeded two and one-quarter pounds per indicated horse-power per hour. The first prize compound engine at the Newcastle trials of the Royal Agricultural Society of England, consumed 1.8 pounds of coal per brake horse-power per hour. The boiler pressure was the same in all the trials, namely, 140 pounds per square inch; feed-water heaters were used, the most economical load was adopted, and the stoking was skillfully done by experienced men. The under-type engines

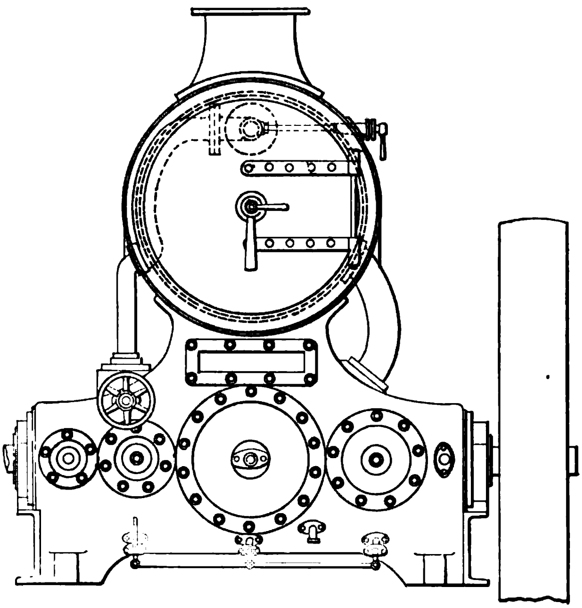


FIG. 5.—END VIEW OF A TRIPLE EXPANSION UNDER-TYPE ENGINE.

* See CASSIER'S MAGAZINE for February, 1893, page 281.

are so constructed that by a very slight modification the engine may be erected independently of the boiler and placed, if need be, in a separate house away from the dust and dirt incident to firing. These separate engines are usually connected with locomotive boilers, but in some instances Cornish, Lancashire, or cylindrical under-fired boilers are used, being specially built for high pressures. A considerable number of water tube boilers are, however, now also employed for electric lighting installations in connection with these engines.

An end view of a triple-expansion under-type engine is given in Fig. 5, from which it will be seen that the low-pressure cylinder is placed in the middle, and the piston rod is extended through the cover for working the air and circulating pumps of a surface condenser. The main and the expansion valves for the high-pressure cylinder are of the piston type, the intermediate cylinder being fitted with an ordinary slide valve at the side, while the low-pressure slide valve is situated at the top of the cylinder as indicated by the cover. The crankshaft is carried in four bearings, the pillow blocks being combined in one casting with the ashpan, which supports the firebox end of the boiler. Steel channel girders of strong section are used for the frame of the engine. From tests carried out with a non-condensing engine of this type, working with a boiler pressure of 175 pounds per square inch, it appears that the coal consumption was at the rate of 1.45 pounds per indicated horse-power per hour.

The engine tested had cylinders five and one-half inches, nine inches, and fifteen and one-half inches in diameter, all of fourteen inches stroke, and was making 150 revolutions per minute, indicating forty horse-power. The cylinders were carefully steam jacketed, but during the trial the feed-water was not heated. From the foregoing facts, it will be seen that the most careful construction enters into these engines which by many are regarded as belonging to a cheap class, and that their economy of operation compares most favorably with that of high class mill engines in which low fuel consumption is looked upon as a matter of course.

MODERN GAS AND OIL ENGINES

By Albert Spies, Mem. Am. Soc. M. E.

Sixth Paper.

EVER since the first practical utilization of gas and oil engines and the satisfactory demonstration of their applicability to general power purposes, builders of such engines have sought to cultivate special fields in which to secure new employment for the motors and, as a consequence, they are found at the present time performing the widest variety of services. Not only as stationary, but also as portable engines, mounted on trucks, for agricultural purposes, as fire engines, pumping engines capable of being rapidly taken from place to place, as locomotive engines driving road carriages, and as marine engines for propelling launches, as instanced repeatedly in the preceding papers, they are successfully used. In fact, there is no line of work that can be readily called to mind in which they are not now either successfully operated, or to which they do not promise to lend themselves with satisfaction. They are no longer the clattering, noisy engines of early years, nor have they retained the excessive bulk and great weight for even moderate powers which characterized some of them when first brought out; instead, they have been made surprisingly quiet in operation, and in size and weight have been brought down almost to the figures ruling in steam engine practice, so that, for the same powers, a modern gas or oil engine and an average steam engine are not very unlike.

Among the many oil engines which probably first became best known in the United States as specially applicable to launch propulsion is the Daimler motor, built in this country by the Daimler Motor Company, of Steinway, Long Island City, N. Y., and introduced also in England by Messrs. Sims & Co., of London. The engine is designed for the use of either gas or gasoline, and is the invention of Mr. Gottlieb Daimler, of Cannstatt, Germany, who for many years was associated with the late Dr. Otto. It is by no means, however, restricted to launch use, but is applicable to all the several motor purposes for which the various engines of its class have been employed. Figs. 82 and 83 represent different views of a single-cylinder Daimler motor, while Fig. 84 shows a double-cylinder design, the motor, it being proper to state here, being made with one or more cylinders according to the power required. Thus, while the smaller sizes are of the single and double-cylinder designs here illustrated, the five and ten-horse-power engines have four cylinders placed side by side.

The principle of operation, however, and the main features of construction are the same in all the engines. For the purpose of our explanation of the manner of working we will take the single-cylinder engine, the cycle of operations applying equally well to all the others, being simply multiplied in number with the increase in the number of working cylinders. Fig. 87 represents a vertical section of one of the engines along the line of the shaft and clearly illustrates the character of the internal construction, the valve mechanism, governor connection and other important working details. Within the

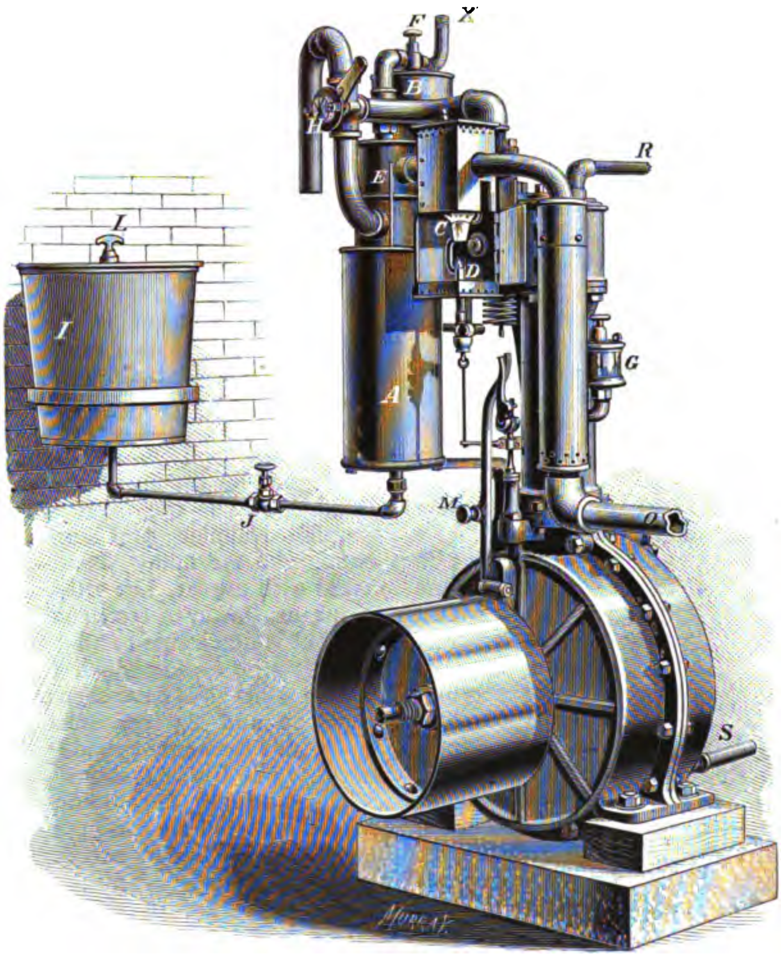


FIG. 82.—SINGLE CYLINDER MOTOR, BUILT BY THE DAIMLER MOTOR COMPANY, NEW YORK.

base of the motor, which consists of a cast iron circular chamber, are arranged two crank discs, mounted upon the two sections of the main shaft and connected by the crank pin, the crank discs serving also the purpose of fly wheels. In one of the discs is formed a double cam groove which passes twice around the crank-shaft and returns into itself. In this cam groove works a follower, or two followers in the case of a double-cylinder engine (see Fig. 85), operating the exhaust valve gear so as to make every other stroke a working stroke, and thus maintaining the Otto cycle. When two or more cylinders are used, they are arranged either parallel with one another, or they are inclined so as to form a slight angle. In the double-cylinder engine both connecting rods work on the same crank pin, and both pistons, therefore, move up and down together; but on the down-stroke one of them is always moving under the impulse of an explosion, while the other is drawing a working charge into its cylinder, and on the up-stroke one of them is always expelling the waste gases, while the other is compressing a charge. Ordinarily, therefore, there is in the double-cylinder engine an explosion in either one or the other cylinder

at every revolution of the crank-shaft. In the engine as arranged for working with gasoline, A (see Fig. 82) is the carburetor; O is the exhaust pipe which is provided with a perforated casing through which the air is drawn on its way to the carburetor, becomes warmed before it reaches the latter, and is thus better able to become impregnated with gasoline vapor. From the carburetor the mixture goes through the valve H which also admits an additional air supply through the open-end, curved pipe, shown at the left, and the charge finally reaches the valve chamber. The small valve F regulates the supply of gasoline to the burner D which heats a platinum ignition tube C. With this ignition tube heated to redness and a few turns given to the engine by means of the crank handle S to draw in the initial working charges, the engine will proceed regularly with its work. A vertical section of the cylinder, valves and crank chamber is given in Fig. 86. The admission valve is held to its seat by a spring and opens inward under the influence of the partial vacuum formed in the cylinder by the suction stroke of the piston. The exhaust valve is similarly kept closed by a spring while the admission valve is open, and is pushed upward and opened to permit escape of the waste gases from the cylinder at the

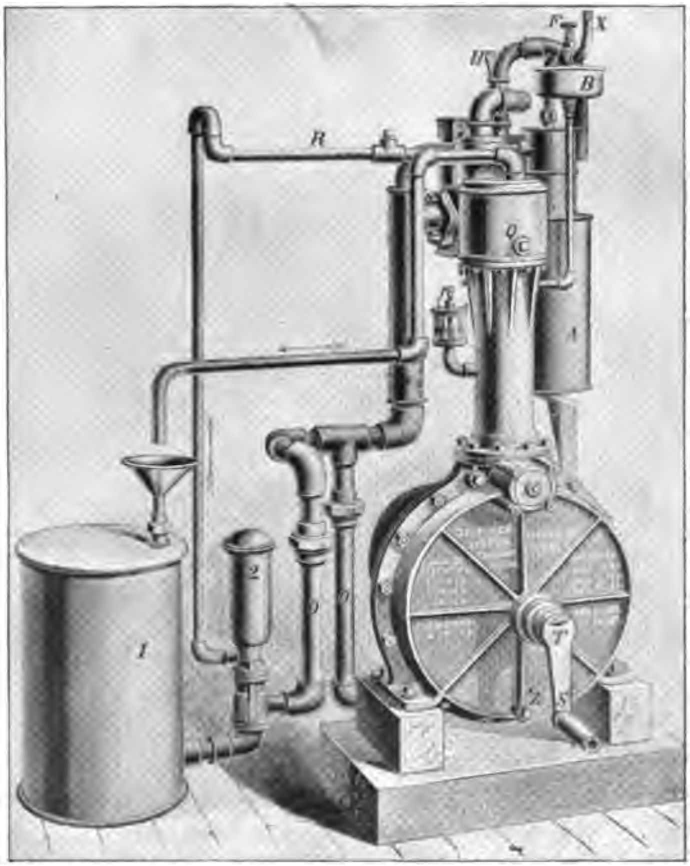
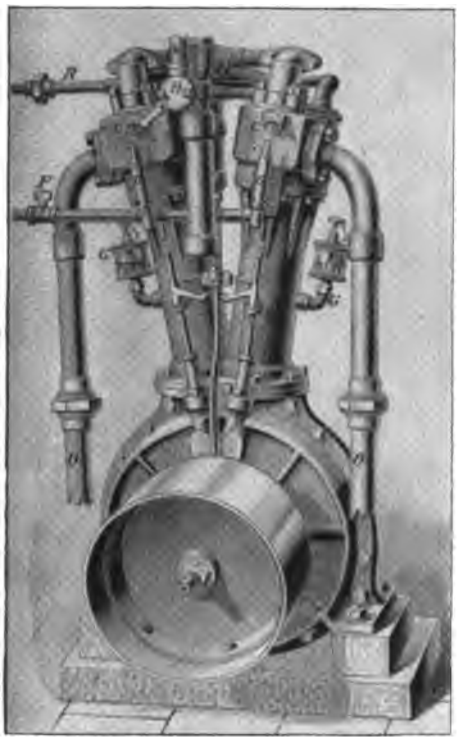
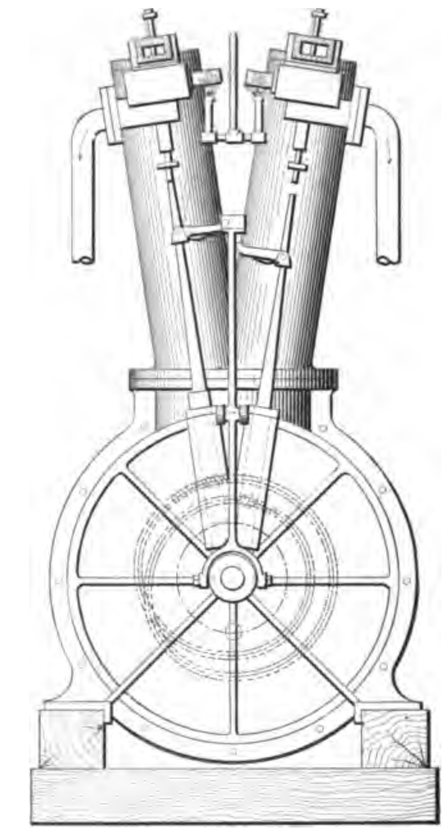


FIG. 83.—SINGLE-CYLINDER DAIMLER MOTOR, WITH COOLING WATER CIRCULATING PUMP.

proper time by the exhaust valve rod which is operated, as previously remarked, by the follower working in the cam groove in one of the crank discs. The governor arrangement is exceedingly neat and simple. The governor, it will be seen, is mounted inside the driving pulley on the crank-shaft, and by means of a sliding collar controls the position of a centrally pivoted rod. When the speed of the engine rises above the normal, the governor weights move charge of explosive mixture can obviously not enter. No impulse can, therefore, take place in the cylinder until the speed has become slower and the exhaust valve rod has been allowed by the governing gear to resume its original position where it can strike the exhaust valve spindle and open the valve.

The pipe R, Figs. 82 and 83, is one





FIGS. 84 AND 85.—PERSPECTIVE VIEW AND ELEVATION OF DOUBLE-CYLINDER DAIMLER MOTOR.

outward, carry the sliding collar along the shaft, and deflect the upper end of the pivoted rod which comes in contact with the upper, jointed end of the exhaust valve rod and turns it to one side. In this position the exhaust valve rod, on its upward stroke, misses the exhaust valve spindle, passing to one side of it, and the exhaust valve consequently is not opened, the waste gases cannot escape from the cylinder, and a new of the water circulating pipes delivering cooling water from a small pump, marked 2, to the jacket Q around the cylinder, another pipe returning the water, which may be used over and over again, to a tank marked 1. Where some other source of water supply is available, the tank and pump may, of course, be dispensed with. In fact the design shown in Fig. 83 is now but little used. With the pump and tank attachment, however,

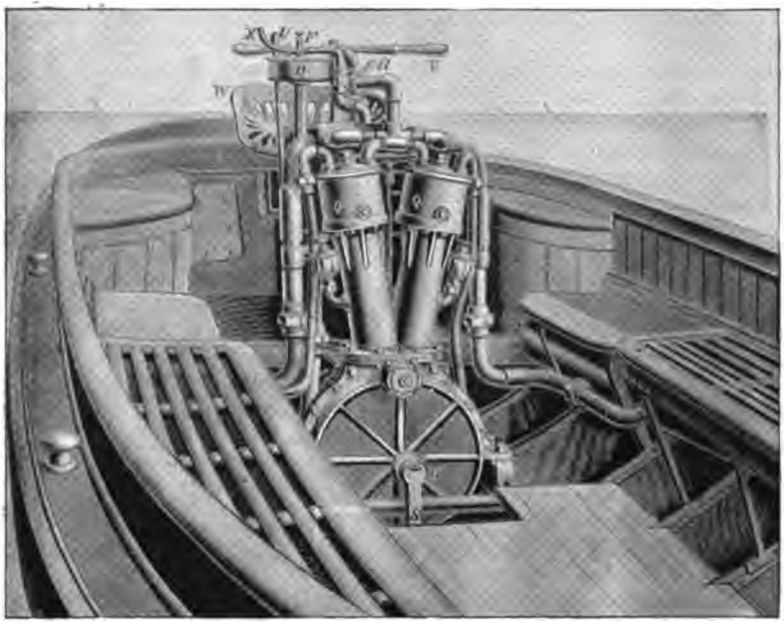


FIG. 86.—A DAIMLER MOTOR LAUNCH.

the motor is entirely self-contained and can be used anywhere, without dependence upon either gas or water mains. The tank I, Fig. 82, serves for gasoline storage and can be conveniently located, outside of the building if desirable.

A float index E on the carburetor A, indicates the level of the gasoline within. When the carburetor is completely charged, the supply will last about five hours. Where the reserve tank I is applicable it will be necessary to charge the outfit only once a day for a running time of ten hours. When gas is available the carburetor and reserve tank naturally are done away with, and the engine assumes a somewhat simpler appearance, as shown, for example, in the illustration of the double-cylinder motor. The single cylinder design is followed for sizes up to one horse-power; beyond that, two and four cylinders are employed. In the four-cylinder engines, and also in some of the two-cylinder engines as built in Germany, the cam-groove exhaust valve gear as here described is not used, but in its place a separate cam shaft, driven by gearing from the main shaft is employed. The general features of design and the manner of working are, however, exactly the same. When used for boat propulsion, the motor is generally completely boxed in so as to protect it against the weather, and is fitted with a suitable reversing gear.

Being of German origin, the engines having first been built by the Daimler Motoren Gesellschaft, of Cannstatt, which is still making them, it is only natural that in Germany and in Europe generally we should find the motor applied most extensively and to the widest variety of uses. At Stuttgart, for example, it is in successful operation in propelling a street car. It has also been applied on some of the German railroads to driving small inspection cars, similar to the familiar hand cars, and has similarly found favor for the propulsion of road carriages, quadricycles and even bicycles, not to mention the large number of pleasure boats which are equipped with it. The English firm of Sims & Company, of London, are actively prosecuting the introduction of the motor into British territory.

Before finally leaving the Daimler motor a little more information concerning the carburetor used may not be amiss. A sectional view of it, with some of its accessories is, therefore, given in Fig. 89. The lower part of the apparatus consists of a small tank H, containing a float B, which rests upon the gasoline. The float is provided with a central funnel which communicates with the main body of the liquid in the tank through a small opening at the bottom, so that while the liquid is maintained at a constant level in the funnel, it is practically isolated from the main body of the petroleum. The float is provided with an air tube entering the funnel, and perforated below the surface of the gasoline. This air tube slides freely in the tube F, attached to the cover of the apparatus and acting as a guide, allowing the float to rise and fall according to the supply of gasoline. Hot air is admitted to the carburetor through the pipe attached to the upper part of the apparatus, the air being heated in its passage to the carburetor by the products of combustion as already explained in describing the engine proper. The carbureted air passes through the vapor pipe in the direction indicated by the arrow, and unites with a stream of air drawn into the motor cylinder through the admission valve at G. This valve is provided with a graduated scale which facilitates the adjustment. It has also an automatically operating safety valve. The reservoir is filled through a supply pipe extending down to the bottom through the air tubes and float. The supply pipe communicates with the lamp font *p*, which furnishes the oil to the burner, by means of which the ignition tube is heated. The time required for heating the latter and starting the motor is inappreciable. The motor may be stopped temporarily by shutting off the supply of combustible gas, allowing the ignition tube burner to continue burning. For a complete stop, however, the ignition tube burner is extinguished in addition to shutting off the gas.

One of the most interesting and ingeniously designed gas engines put on the market by English makers is the Atkinson differential engine, first brought out eight or nine years ago by the British Gas Engine & Engineering Company, of London. The main object

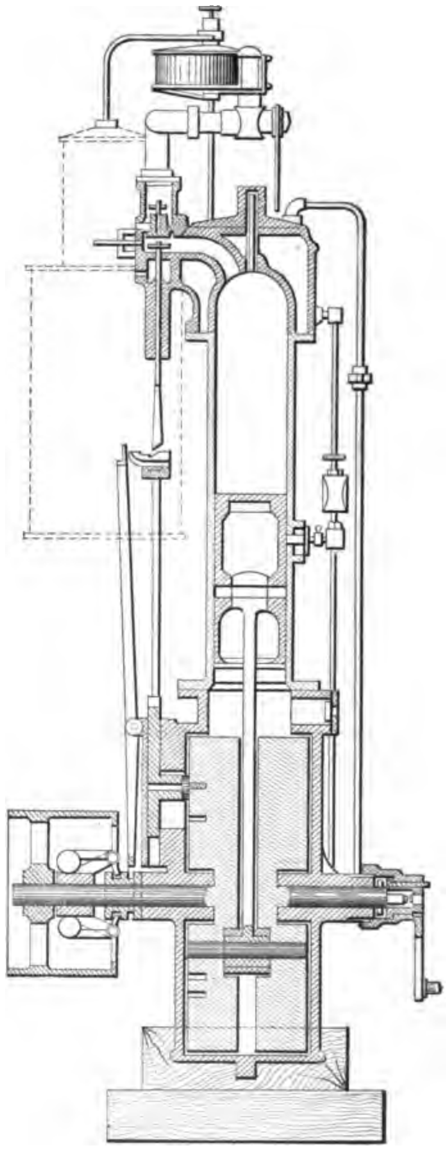


FIG. 87.—SECTION OF DAIMLER MOTOR.

sought after in this engine was to allow the exploded charge to expand much more rapidly than is usual or possible in most other gas engines, and to thus be in contact with the relatively cold cylin-

der walls for a shorter period of time. In this way, it was agreed, an important economical end is served.

The engine in its earliest form is shown diagrammatically in Figs. 91 to 94, from which the main peculiarities of its operations will be more clearly understood. The cylinder in this early design was open at each end and had two pistons connected by curved levers and short connecting rods to one crank pin. The through a port in the cylinder wall. The crank pin was, at this time, on the left, and as it proceeded upward and around to the right, the left-hand piston moved rapidly away from the other, leaving a space between them into which the gas and air mixture was drawn through a self-acting suction valve. When the crank pin had reached its highest position, as in Fig. 92, the right-hand piston traveled past and closed the openings to

FIG. 88.—QUADRICYCLE PROPELLED BY A DAIMLER MOTOR.

pistons both traveled in the same direction but at very different speeds. When at the outer end of their stroke, they remained almost at rest for nearly half a revolution of the crank pin, but when at the inner end of the stroke they traveled rapidly. When the pistons had completed a stroke to the right, as in Fig. 91, they almost touched each other, and had driven out the products of combustion of the previous working stroke the suction and exhaust valves, and during the next quarter turn the pistons again approached each other, compressing the explosive charge between them, the crank pin by that time being over at the right-hand side, as in Fig. 93. At the moment of greatest compression, the left-hand piston passed an opening to an ignition tube which produced explosion of the charge, and an immediate, rapid stroke was made by the right-hand

piston and was completed by the time the crank pin arrived at the lower quarter, as in Fig. 94. The exhaust port was then opened by the continued travel of the piston, and the contents of the cylinder were driven out through the self-acting exhaust valve by the left-hand piston which assumed the position shown in Fig. 91, the whole cycle being completed in one revolution of the crank-shaft.

The space between the pistons into which the ignited charge expanded was nearly double the space into which the charge was first drawn previous to explosion; consequently, the expansion amounted to nearly twice the original volume, and the terminal pressure at which the gases were expelled from the cylinder becomes very low. It will also be observed that the total expansion to twice the original volume took place in a quarter revolution of the crank-shaft as compared with other gas engines and this expansion to double the original volume was accomplished in one-fourth of the time taken for the same degree ot expansion in other engines, assuming the engine to run at the same speed. The economy to be gained from the extra expansion is obvious, while the saving due to the rapid motion of the piston is also beyond question, having been conclusively demonstrated experimentally by a French authority, Professor Witz, a number of years ago.

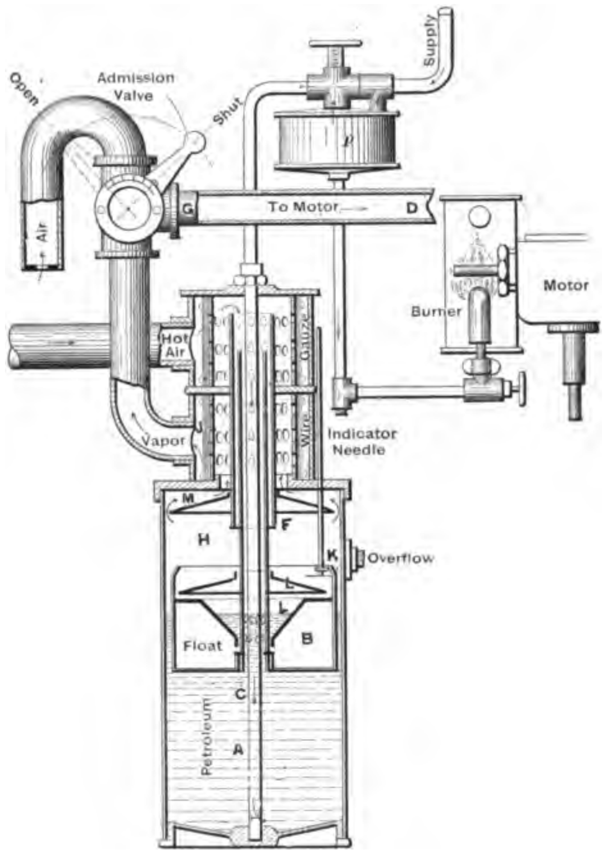


FIG. 89.—SECTIONAL VIEW OF THE CARBURETOR USED WITH THE DAIMLER MOTOR.

Without going in detail into the experiments made by him, it may not

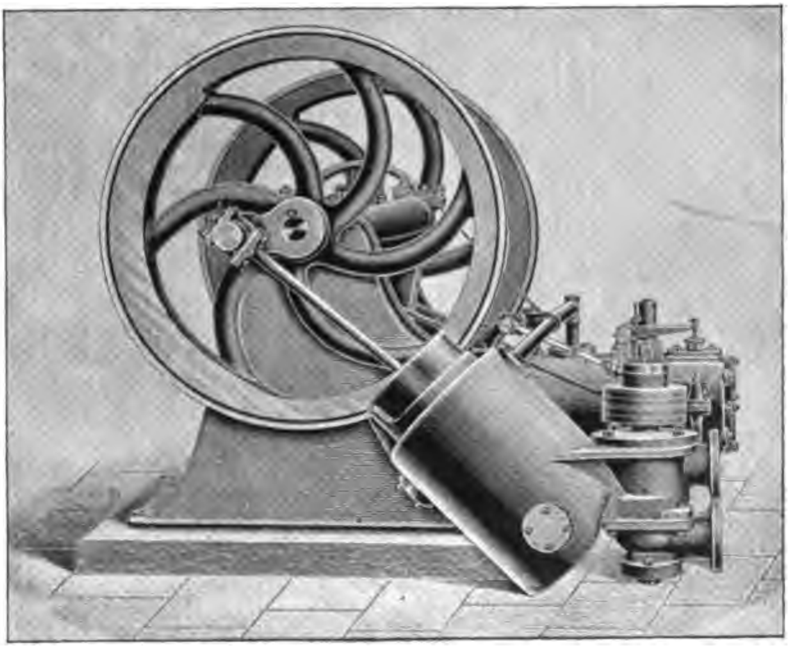


FIG. 90.—ATKINSON'S MODERN GAS ENGINE AND AIR COMPRESSOR COMBINED.

be uninteresting to here briefly state that in one series of experiments he used a mixture of one volume of illuminating gas and 6.33 volumes of air—a not unusual proportion for gas engines. This mixture was drawn into an experimental cylinder and exploded, the piston being allowed to travel at the rate of 1.7 meters per second, corresponding to an ordinary piston speed in a medium-sized gas engine. The actual amount of work done was estimated from a diagram obtained from the cylinder. He then increased the speed of the piston, and found that by allowing the piston to move at the rate of 4.3 meters per second, or 2.54 times as fast as before, the same amount of gas did 2.9 times as much actual work. This large increase is chiefly due to the fact that the heat of combustion of the gaseous mixture is, at the higher speed, not allowed to continue so long in contact with the walls of the cylinder which are kept cool by the customary water jacket. It has been held that more than one-half of the total heat in the gas, even if thoroughly consumed, is lost by transmission to the water. If then the work is done in one-fourth of the time, as in the Atkinson engine, three-fourths of this serious loss must be saved, since the transmission of heat through metallic substances is directly proportionate to the length of time that the differences of temperature exist; hence, the great increase of power shown by Professor Witz's experiments.

The engine in its early form was extremely simple. There were no slide-valves, nor were there any complicated substitutes, the working charge being efficiently controlled by the pistons passing the ports to the two self-acting valves and the port to the ignition tube. There were also neither cams nor eccentrics. In the course of the last few years, however, the design of the engine has undergone some changes, so that at the present time its appearance is like that shown on this page.

The "Utilité" gas engine, built by the same firm, was not designed as a rival to their standard engine, but

simply as an alternative motor for obtaining practically the same results and, to a certain extent, to meet the varied views of buyers of gas engines. Perhaps the most distinctive feature of this later engine is found in the fact that the crank end is cased in and the space thus afforded is used as an air chamber whose supply serves to flush out the cylinder after each working stroke, the waste gases being allowed to escape through an opening in the side of the cylinder uncovered by the piston in its travel. There is thus no exhaust valve of the usual kind. After the flushing of the cylinder has taken place, a small charging pump delivers into the firing end of the cylinder a rich mixture of fresh gas and air, the air proportion, however, being insufficient to permit explosion until it has been further added to.

The piston, after having made a working stroke, returns and is allowed to expel through the exhaust opening some of the cylinder contents which, at the piston end of the cylinder, are made up of waste products of combustion or, perhaps, simply air. At about half the return stroke, however, the piston closes the exhaust opening or port, and what then remains in the cylinder is air and gaseous mixture in more or less definitely separate layers, the gas mixture being in the firing end of the cylinder, and the air alone, in the piston end. As compression takes place, the air and gas and air mixture become more intimately mixed and by the time the cylinder contents are fully compressed they are in a proper condition for ignition which then takes place; a working stroke is made in this manner once for every revolution of the crank-shaft. A small valve, in addition to the exhaust opening in the cylinder wall, controlled by an eccentric, allows a portion of the air to be removed from the cylinder before the compression stroke is completed, so as to leave only about one-half the original cylinder contents shut up, which, after compression and ignition, is allowed to expand to double its original volume. As a result, the diagram from the engine is practically the same as the diagram from the regular Atkinson engine, and the economy of the two is claimed to be practically the same. It is further claimed for the "Utilité" engines that they combine great lightness with rigidity and that they can be run at very high speeds without heavy foundations and without causing any trouble from excessive vibration. Speeds as high as 600 revolutions per minute are claimed to have been maintained with good results.

One of the later types of vertical gas

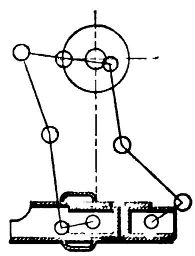


FIG. 91.

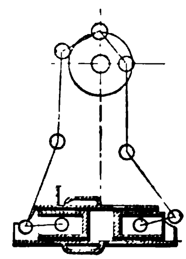


FIG. 92.

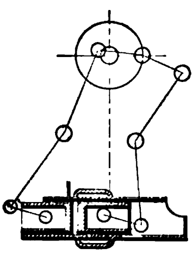


FIG. 93.

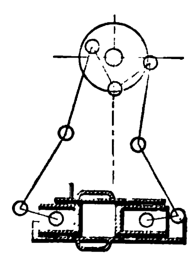


FIG. 94.

DIAGRAMS OF THE ATKINSON DIFFERENTIAL ENGINE.

engines is that made by the Hartig Standard Gas Engine Company, of Brooklyn, N. Y., both single and double fly-wheel designs being shown in Figs. 95 and 96. There are, in all, four valves in this engine,—a governor valve, automatically controlling the gas supply according to the amount of power required, a lighting valve, a gas and air admission valve, and an exhaust valve. The governor valve is in the main gas supply pipe and is worked by the vertical rod shown at the extreme left of Fig. 95. The governor itself is of the shaft type, the centrifugal force of the two weights being restrained by springs attached to the weight arms and to the

weights in the manner indicated. With increase in speed above the normal, the weights move outward, and revolve a cam, mounted on the crank-shaft and provided with a helical groove and pin arrangement which causes the cam to slide in and out along the line of the shaft. When moved inward, that is, from left to right in the engraving, the cam comes in contact with another and smaller cam, directly connected with the main gas valve rod, and causes the valve to close more or less, thus shutting off the gas supply or simply reducing its volume, and consequently bringing about a decrease in speed. With the lower speed the governor weights return to their original position, the cams are thrown out of contact, and the gas supply valve is again opened.

The exhaust valve is worked by the rod shown furthest to the right in the engraving, and receives motion from the crank through the intervention of two gear wheels, one of which has twice the diameter of the other. The valve is thus opened once in every two revolutions, the engine working on the Otto cycle. The valve rod connects with a valve lifting arm pivoted at one end,

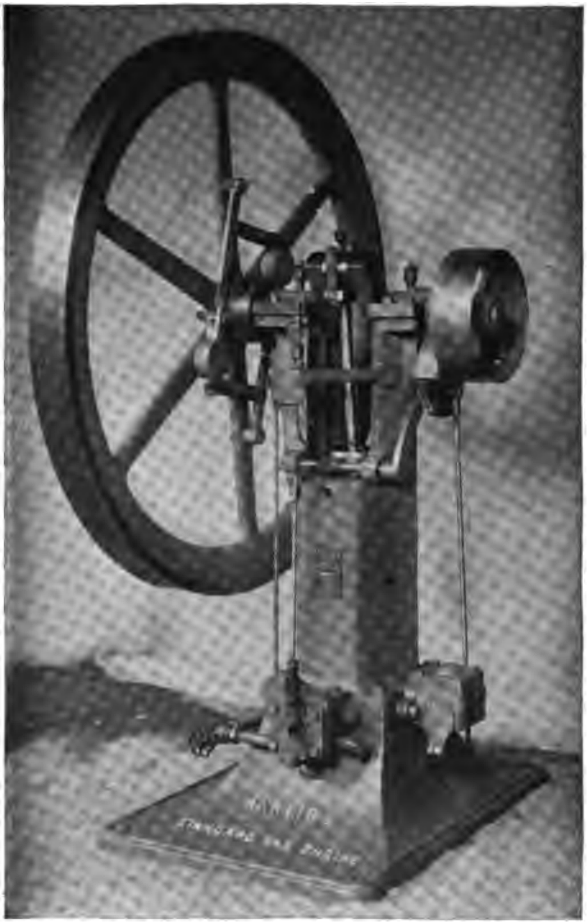


FIG. 95.—THE HARTIG ENGINE, BUILT BY THE HARTIG STANDARD GAS ENGINE COMPANY, BROOKLYN, N. Y.

and, in its upward motion striking the valve spindle from below and lifting the valve from its seat to which, ordinarily, it is held by a spring. The igniting valve at the front of the engine is operated by a rod connected with a rock shaft, mounted on the engine frame as clearly shown, and receiving motion from the crank shaft through a rocker arm and cam gearing. The igniting gas jet burns at the side of this valve and, at the moment of valve opening, communicates with the explosive mixture in the cylinder and fires it. The gas and air admission valve, located almost directly behind the igniting valve, is not worked by any rod or gearing, but opens under the influence of the partial vacuum formed in the engine cylinder during the suction stroke of the piston, and closes of its own accord during the compression period, remaining also closed, for obvious reasons, during the working and exhaust strokes. The valves all are of the lift type, insuring lightness and freedom from sticking and clogging. The engine is made in sizes of from one to eight horse-power, though a small half horse-power pump and engine combination is also turned out.

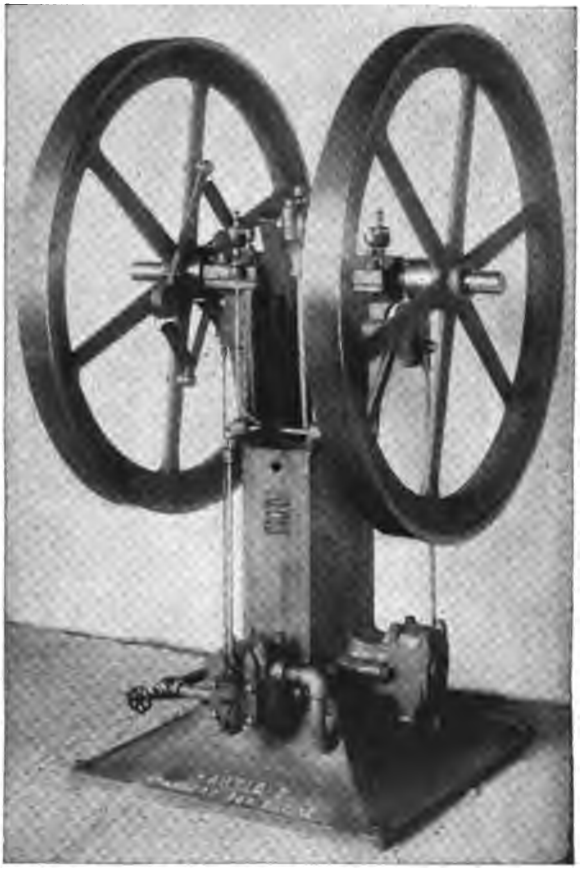


FIG. 96.—HARTIG DOUBLE FLY-WHEEL ENGINE.

Experience with this engine has shown that it is well adapted to the driving of electric light dynamos, and it is for this work that its builders make one of their strongest claims, being specially pre-

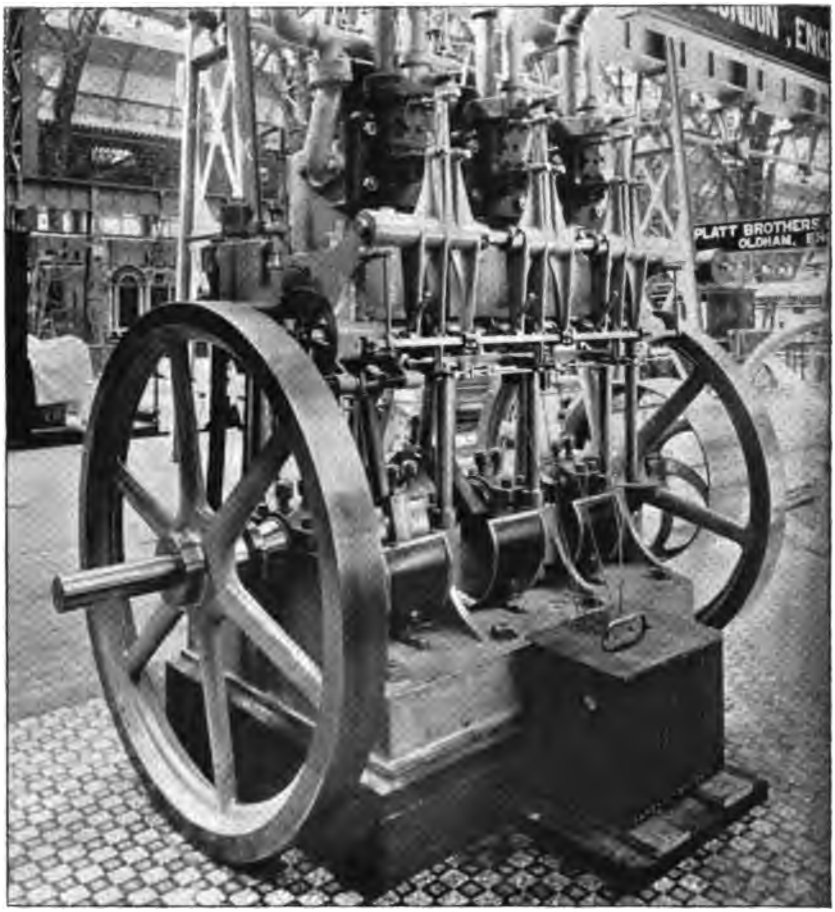


FIG. 97.—THREE CYLINDER "TRUSTY" OIL ENGINE AT THE WORLD'S FAIR.

pared to furnish gas driven, isolated electric light plant outfits.

A petroleum engine in which the now so widely used Otto cycle is not followed is that built by Messrs. Penney & Co., of Lincoln, England, and known as the Weatherhogg engine. In this a practical application is made of the six-stroke cycle, already referred to in one of the preceding papers, a scavenger charge of air being taken into and discharged from the cylinder during the interval between exhaust of the products of combustion and the admission of the working charge.

The oil is injected into a vaporizer by a pump, which acts only when the speed of the engine is normal or less, being operated by a hit-and-miss device controlled by the governor. The oil is delivered into a coil heated by a blowpipe flame, and is there vaporized under pressure. The flame is produced from a spray of petroleum, and is fed by compressed air from a pump, which can be worked by hand at starting.

When starting the engine, a handle is fixed to the crank which works the pump, and it is rotated by hand for a few minutes, until the coil is hot. The oil is then injected and the vapor is allowed to accumulate until it attains a considerable pressure, which is maintained during working. It is claimed

that better results are obtained by this pressure, and that it enables crude petroleum to be used if required. The pressure can be regulated by adjusting a throttling device at the outlet of the vaporizer. Between the vaporizer and the cylinder is the air admission valve, contained in a box in which mixture of the charges take place, ignition being effected by a heated tube. In some cases a part of the air is taken from a box in which the crank and connecting-rod are inclosed, and in this way any leakage past the piston is caught and prevented from escaping into the engine room.

In connection with the "Trusty" double-cylinder oil engine shown in the June number, it is of interest to direct attention to a vertical, three-cylinder oil engine built by the same firm, Messrs. Weyman & Hitchcock, of Guildford, England, and shown at the World's Fair at Chicago. The principle of operation is essentially the same as that of the engine already described. The three cylinders are connected to a three-throw crank shaft, with the cranks set at angles of 120 degrees, so that the work of the cylinders is well distributed throughout the period of each revolution. The valve gear is worked from a cam shaft driven by worm gearing, but each cylinder has its separate cams so that any one of them may be cut out at will.

(*To be continued.*)

ANHYDROUS AMMONIA GAS AS A MOTIVE POWER.*

By T. Waln-Morgan Draper.

THE burning question of the hour now is : "What power shall supplement or succeed steam and other forces hitherto used by mankind, yet now found inadequate to meet the growing developments of science and civilization?" This question, like Banquo's ghost, will not down, nor has the very useful broad utility of electricity settled the problem in a satisfactory manner, principally on account of its cost. Many bright people are endeavoring to discover a force which shall fulfil the conditions of tractability, safety and economy, as yet without success.

In some experiments upon ammonia as a motor fluid, recently conducted by myself, under the inventions of others, and by subsequent close study and investigation, I believe that the conditions above referred to, have been more nearly fulfilled than in any other process heretofore proposed for its use.

Ammonia gas has a density of .596 (air being 1.0); its volume is 983 times greater than the space occupied by its liquor, whilst steam under identical pressure occupies a space only 303 times greater than water. The latent heat of ammonia is about 752 degrees, that of water being 990 degrees. Ammoniacal gas is absorbed with avidity by water, one volume water at eighty degrees Fahrenheit, absorbing about 700 volumes of gas. The water becomes specifically lighter, while its volume is being augmented one-third. As the absorption of the gas goes on, the water becomes heated, and the latent heat of the gas reappears as sensible heat. It is in this property that water possesses of absorbing such volumes of gas and of becoming heated whilst doing so, that the practicability of using this gas as a motive power rests, always bearing in mind that heat is the prime agency for producing gas. Ammoniacal gas can be liquefied by pressure and frozen by a mixture of solid carbonic acid and ether in a vacuum.

Both water and ice absorb ammonia with great avidity, with considerable evolution of heat, and with great expansion. Davy found that one volume of water at a temperature of ten degrees C. and 29.8 inches barometric pressure absorbs 670 volumes of ammonia, or nearly half its weight; the specific gravity of this solution is 0.875. Aqueous ammonia is a colorless transparent liquid, smelling of ammonia, and having a sharp, burning, urinous taste. Its specific gravity varies from 1.0 to 0.85, according to the amount of ammonia contained. Its boiling point varies according to the percentage of ammonia and its specific weight. At a specific gravity of 0.85 and 35.3 per cent. ammonia, its boiling point is $-4°$ to $+92°$ when its specific gravity is 0.99, and its percentage of ammonia is 2.0. A perfectly saturated solution freezes between $-38°$ and $-40°$ C., forming shining flexible needles. At $-49°$ C. it solidifies to a gray gelatinous mass, almost odorless. It loses almost all its ammonia at a temperature below 100 degrees C. Aqueous ammonia possesses the property of dissolving many salts which are not soluble in water, chromic and stannic oxides, the protoxides of tin, cadmium, and zinc, the oxides of copper and silver, these combinations being decomposed by heat, losing ammonia.

In order to determine the percentage

* From a paper presented at the International Engineering Congress at Chicago.

of ammonia in any given solution of what is commonly known as "commercial ammonia," I have found the following table of great value and practically correct :

$\frac{1}{16}$°	Beaume =	0.117	per cent.	ammonia.
$\frac{1}{8}$°	"	0.234	"	"
$\frac{1}{4}$°	"	0.468	"	"
$\frac{1}{2}$°	"	0.931	"	"
11°	"	1.87	"	"
12°	"	3.75	"	"
13°	"	5.62	"	"
14°	"	7.5	"	"
15°	"	9.37	"	"
16°	"	11.25	"	"
17°	"	13.12	"	"
18°	"	15.0	"	"
19°	"	16.87	"	"
20°	"	18.75	"	"
21°	"	20.62	"	"
22°	"	22.5	"	"
23°	"	24.37	"	"
24°	"	26.25	"	"
25°	"	28.12	"	"
26°	"	30.00	"	"

The initial temperature of steam at 150 pounds pressure is 446 degrees Fahrenheit. Anhydrous ammonia gas at the same pressure has a temperature of 80 degrees.

The relative proportions of the two are :

	Water.	Ammonia.
Latent Heat,	990	752
Relative Volume,	1728	.1313.28
Boiling Point,	212° Fahr.	—38.5° Fahr.
Ratio,	100	.76

The temperature and pressure exerted by ammonia gas are founded on the relative points as ascertained in practice ; at a temperature of sixty degrees Fahrenheit, there is exerted a pressure of 110 pounds, and at eighty degrees Fahrenheit, a pressure of ten atmospheres, or 147 pounds, the proportion being : 20 : 37 :: 1° : x.

The following pressure table is made up from actual practice, and may be regarded as substantially correct :

A temperature of		Exerts a pressure of	
50°	Fahr.	92.5	pounds.
51°	"	94.35	"
52°	"	96.2	"
53°	"	98.05	"
54°	"	99.9	"
55°	"	101.75	"
56°	"	103.6	"
57°	"	105.45	"
58°	"	107.3	"
59°	"	109.15	"
60°	Fahr.	110.0	pounds.
61°	"	112.85	"
62°	"	114.7	"
63°	"	116.55	"
64°	"	118.4	"
65°	"	120.25	"
66°	"	122.1	"
67°	"	123.95	"
68°	"	125.8	"
69°	"	127.65	"
70°	"	129.5	"
71°	"	131.35	"
72°	"	133.2	"
73°	"	135.05	"
74°	"	136.9	"
75°	"	138.75	"
76°	"	140.6	"
77°	"	142.45	"
78°	"	144.3	"
79°	"	146.15	"
80°	"	147.0	"
81°	"	149.85	"
82°	"	151.7	"
83°	"	153.55	"
84°	"	156.4	"
85°	"	157.25	"
86°	"	159.1	"
87°	"	160.95	"
88°	"	162.8	"
89°	"	164.65	"
90°	"	166.5	"

If smaller or greater pressures are required than those given in the table, it becomes simply a question of lowering or raising the temperature.

Anhydrous ammonia, or dry ammonia gas, condenses to a liquid at —38½° Fahrenheit, or it can be condensed by a pressure varying from 150 to 185 pounds at a temperature of + 70° Fahrenheit. On the removal of this pressure, the gas expands fully. This is not entirely availed of in the ammonia motor, as during its expansion it is used like steam to drive the piston of an engine. The gas is as easily handled as steam, quite as safe, far cheaper, and in many respects resembles steam.

There have been a great number of engines invented and patented, using ammonia gas alone, or in combination with other vapors, as a motive force. Such motors have been invented by Gamjee, Seyforth, Jean Foot, Lamback, Dr. Emile Lamm, and many others, who, with two or three exceptions, have gone about the work in hand as patenters and copyists, and

not as true inventors. At any rate, the patent offices are full of their claims. Enough has been accomplished, however, to demonstrate that the ammonia engine is a practical success, and no longer a theory and an experiment; and, further, that ammonia gas alone, and not combined with other vapors, is the true solution of this subject. The ammonia locomotive is not perfect to-day, nor is our older friend, propelled by steam, but it will be very soon.

M. Fromont's ammoniacal engine was exhibited at the Paris Exposition of 1868. His motive power was a vapor containing eighty per cent. ammonia and twenty per cent. steam, which latter was, as you will learn later, directly contrary to the present method, where the endeavor is to obtain as dry a gas as possible, and thereby a perfectly pure anhydrous ammonia liquid. Fromont's engine, however, demonstrated one thing, viz., its economy, as it consumed only one-quarter as much fuel as a steam engine of like power and under the same conditions.

Gamjee's engine, called the "Zero-motor," was intended to use ammonia gas as the power agent. It was a thermodynamic engine, and one with a closed circuit, with a liquid boiling at a low temperature, relatively to water transformed into vapor, the molecular energy of which is converted into the mass or molar motion of the piston, so that its initial condition is restored. In this manner, in a heat engine, the temperature is extended within which the heat is utilized downward, in the direction of the absolute zero, instead of upward, above the temperature of surrounding objects.

The first law of thermodynamics is: "Heat and mechanical energy are mutually convertible in a certain ratio." The second law: "It is impossible for a self-acting engine, by means of inanimate material agency, to derive mechanical effect from any portion of matter by cooling it below the temperature of the coldest of surrounding objects." Clausius, who first clearly defined Carnot's principle, says: "It is impossible for a self-acting engine, unaided by any external agency, to convert heat from one body to another body at a higher temperature."

I refer to these thermodynamic laws here, as they bear directly on the principles of the ammonia engine as now worked out. The invariable principle, that the same cause (under the same circumstances) produces the same result, is applicable to both steam and ammonia (the law of Mariotte), which is invariably the same, viz., that all gases or vapors expand equally by the same degree of heat added to their specific heat. However, ammonia is slightly an exception to this, and greatly in its favor.

Gamjee made the following statements. "Anhydrous ammonia at 0 degree C. has a vapor tension of 3,183.34 mm., or about four atmospheres. At ten degrees it reaches 4,574.03 mm., or six atmospheres. At twenty degrees the pressure is 6,387.78 mm., or nine atmospheres. At thirty degrees (tropical heat) it is over 8000 or ten and one-half atmospheres. Since at blood heat 200 pounds to the square inch is available, it is evident that the usual temperature of ocean or river water is most desirable in practice, and best when below twenty degrees C. The latent heat of ammonia is used in developing energy so as to reduce the amount of rejected heat to a minimum, and to obtain a maximum of liquefaction." Gamjee's engine was a double cylinder rotary engine.

It is the remarkable affinity of ammoniacal gas for water, by which it is able, at any time after its condensation into a liquid, to reproduce, at a distance from where it was condensed, a force equal to the heat which was necessary for its condensation, which makes the ammonia gas engine a possibility.

The most important of the older engines was that of Dr. Emile Lamm, later ones, in their principles, following his closely. In 1870, in describing his engine, he said: "This reproduction is owing to the fact that the latent heat of the gas appears anew in water of reabsorption, and is retransferred to the liquified gas. This takes place through

metallic tubes of which the reservoir is composed, from the water of reabsorption which surrounds them, and is similar in its operation to the action of fire in the furnace of a steam boiler."

Lately we have vastly increased the number and dimensions of these tubes over those thought sufficient by Dr. Lamm, because, although we find that a small evaporation surface would demonstrate the utility, yet for practicable purposes a large evaporating or heating surface was necessary. At a single step this surface has been increased for one horse-power from five to thirty square feet, and has been found economical in many ways.

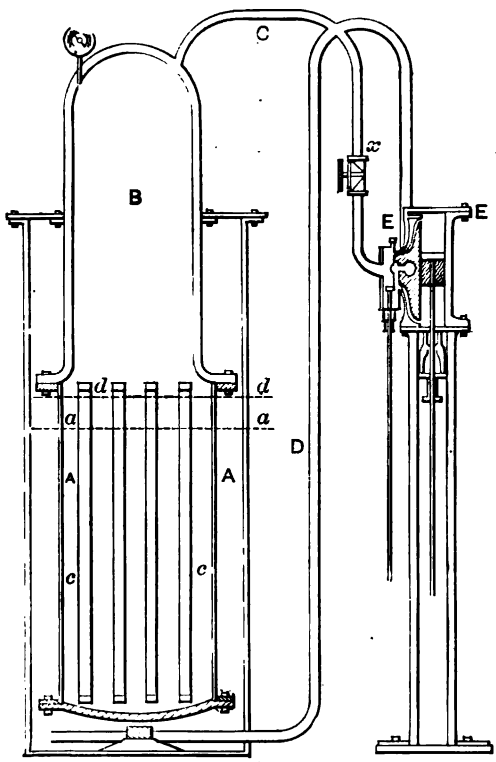


FIG. 1.—DR. LAMM'S AMMONIA ENGINE.

By reference to Fig. 1, which is Dr. Lamm's engine, the arrangement just spoken of will be easily understood :—*cc* is the ammonia reservoir filled with the anhydrous liquid to the line *dd*. *AA* is the tank filled with weak ammoniacal water to the line *aa*. *C* is the pressure pipe leading to the engine *EE*. *D* is the exhaust pipe leading from the engine to the water in the bottom of the tank *AA*. When, by means of the throttle valve *x*, the gas in the reservoir *B* is permitted to act on the piston of the engine, through the pressure pipe *C*, the engine begins to work with a force equal to 150 pounds to the square inch, at a temperature of ninety degrees Fahrenheit; consequently the whole apparatus must remain at a temperature of ninety degrees Fahrenheit to give an effective pressure of ten atmospheres for any given time that may be desired.

One of Dr. Lamm's engines, propelling a street car on a seven-mi e run, was equal to two horse-power; the liquid ammonia expended was 1.16 cubic feet. Therefore, the latent heat

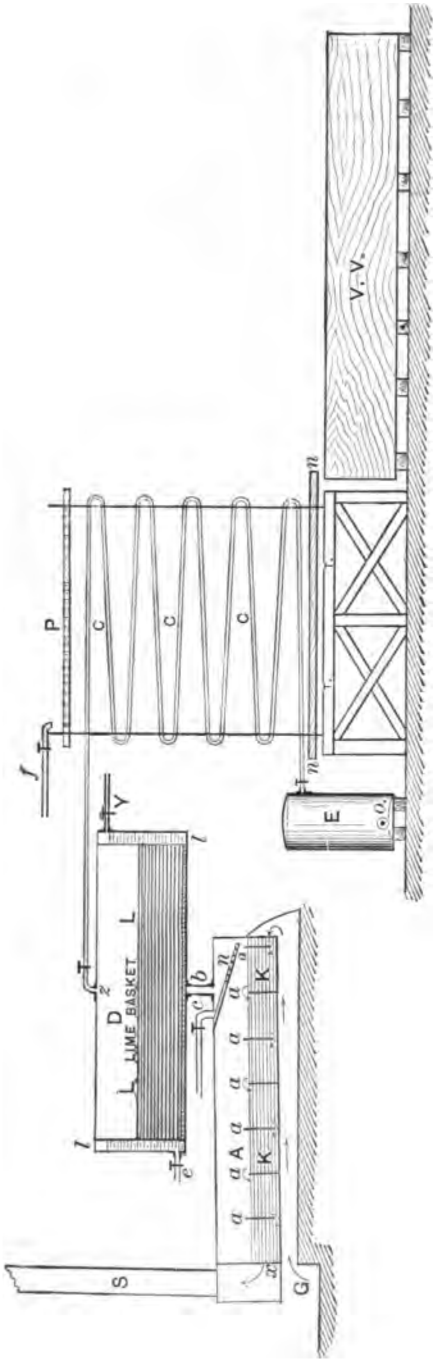


FIG. 2.—PLANT FOR MANUFACTURING ANHYDROUS AMMONIA.

of ammonia gas (according to Dr. Lamm) being 880, the whole heat expended during the trip made was sufficient to raise eighty-four gallons of water from a temperature of eighty-three degrees to the boiling point, 212 degrees.

I will now proceed to discuss and describe the ammonia manufacturing plant and the ammonia engines as they are now, in the light of the latest improvements.

The chief difficulty with all plants for the manufacture of anhydrous ammonia liquid has heretofore been, that the gas which it has been sought to condense, contained more or less aqueous vapor, which, remaining with and being condensed with the gas, resulted in a liquid not absolutely pure, and robbed it of its power to some extent.

In Fig. 2 is shown a design, an improvement on one actually in operation, which meets this difficulty in a most satisfactory way. I will say in advance, that it is absolutely necessary that all parts of such a plant shall be so constructed as to withstand in all its parts a pressure of at least 200 pounds to the square inch.

A is a solution boiler, or still, similar in construction to an ordinary tubular boiler, so set that the end next the stack *S* is slightly lower than the other. The grate is at *G*, and the heat passes first beneath the boiler, thence back through the tubes, and out at the stack. No great heat is required, 122 degrees Fahrenheit sufficing. The ordinary commercial ammonia is introduced at *c*, and falls on a scattering plate and thence on the tubes *kk*. There are a number of upright partitions *aaa*, the first one being raised just above the bottom of the boiler, the next one being all the way down, the next above, and so on. These partitions are merely thin sheets of boiler iron, through which the tubes pass, their object being, in connection with the sloping setting of the boiler, to force the ammonia solution to follow the course indicated by the arrows, in order that it may, by means of the heat, become thoroughly deammoniaized. This latter operation

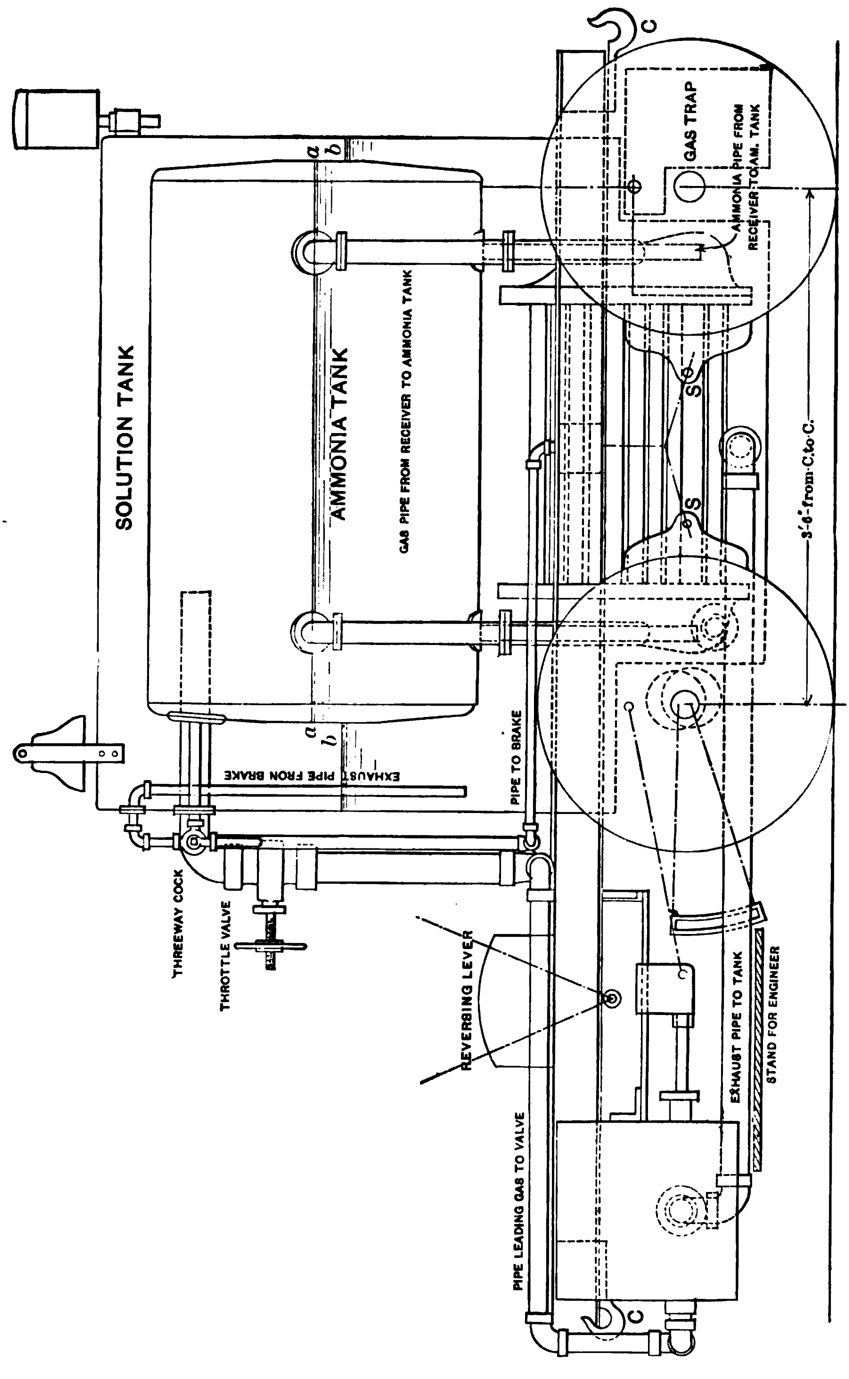


FIG. 3.—SIDE ELEVATION OF AN AMMONIA LOCOMOTIVE.

begins immediately when the solution commences to fall on the tubes through the scattering plate, and it is so thoroughly effected, that by the time it reaches the blow-off point at *x*, it contains usually not over five per cent. ammonia. The gas, as it evaporates, rises from the boiler, through the scattering plate and the inpouring solution, to and through *b*, into what is called a dehydrator *D*. The gas is accompanied by aqueous vapor, and the object of the dehydrator is to free it from this. The dehydrator is a long cylinder, having at either end a water compartment *ll* connected with a series of tubes. On the bottom of the cylinder is an angle-shaped perforated plate; the gas rising from the boiler meets this perforated plate, which scatters it all along and around the tubes, through which cool water let in at *Y*, and passing off at *e*, is constantly flowing. Just above the tubes is a wire basket filled with lime. the pieces being about the size of peas. The partially dehydrated gas, from contact with the cool tubes, now passes through the bed of lime, which is about two inches thick, and is there freed of its watery vapors, and becomes fully dry. By this means one obtains in the upper, or storage, part of the dehydrator, a perfectly dry gas, which, passing out of the top at *z*, flows to the coils *CCC*, where it is condensed, and falls by means of gravity, and the pressure from the still (150 pounds) behind it, into the storage tank *E*. There are ten rows of condensing coils, only one of which is shown in the figure; each row has a total length of 100 feet. The condensation is accomplished by means of very cold water falling from the scattering table *P* over the coils. In order that this water may not be wasted, it is caught in a tray *nn* below, and conducted to a series of wooden vats *VV*, where it is allowed to cool, and used over and over again; it can also be artificially cooled in the same manner as is done in the cold storage plants.

Figs. 3, 4, 5 and 6 represent an ammonia locomotive recently designed for transfer purposes, intended to be used on a cable road for shifting the cars on and off the cable, into or out of the car shed. The house space of the company being limited, their engineers arranged an electric traveling table, and on this a turn-table; the latter was, of course, quite limited in length, only long enough to allow of a thirty-six-foot car and a motor ten feet over all. In addition to this, the company's engineer imposed, on account of balance of the table, that the total weight, with charge, of the motor, should not exceed three tons, and at the same time should have a traction force of 1,000 pounds; total height above rail, ten feet; speed, not less than six miles per hour, and this speed to be attained in six seconds. Further, the shifter must be able to run a reasonable length of time without recharging. The annexed drawings illustrate the design made to fill these specifications. I have made some slight changes from the original designs, notably in placing the gas trap forward of the front axle, instead of just behind the rear axle, and have obtained thereby a more perfect distribution of weight. I have also largely increased the amount of evaporating surface, by doubling the number of the tubes, adding thereby to the quickness of evaporation and the pressure. Its power is vastly increased, as is its speed, by these changes, without overstepping the limits of weight, etc., imposed.

The locomotive shifter is direct-acting. I have endeavored in the drawings to make everything so plain that description would be largely avoided. The inner or anhydrous ammonia liquid tank, of three-eighth inch boiler iron, is to contain the charge, in this case calculated amply for a fourteen-mile run. This charge fills half the tank, the upper half serving as a gas reservoir. Below this tank is hung the evaporator, manifolded at either end. The evaporator and the ammonia tank are enclosed in one large outer, or solution, tank, which is partially filled with water, or the blow-off solution from the still (containing about five per cent. ammonia) to the line *bb*. The engine cylinders are placed on the frame at the

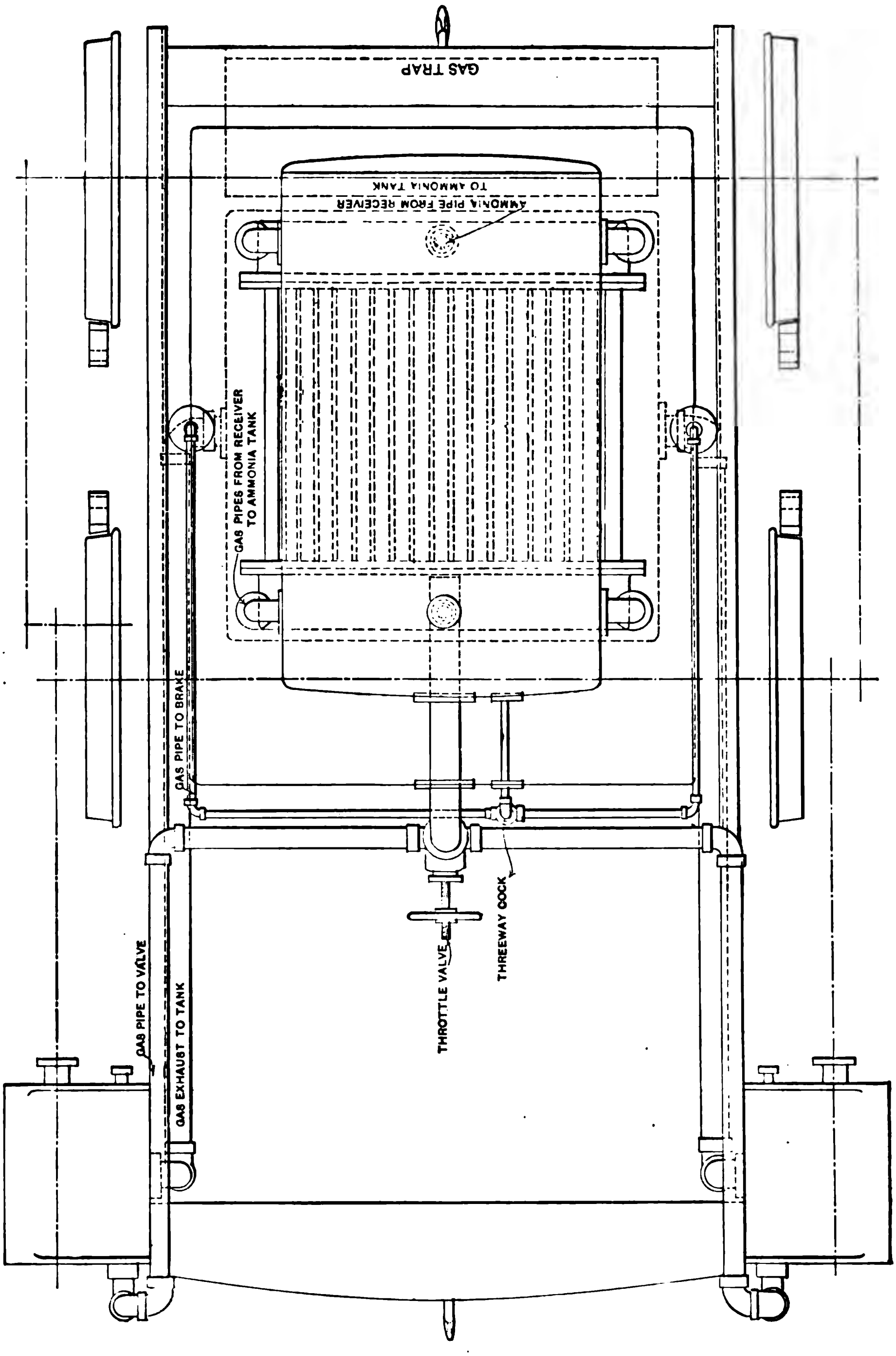


FIG. 4.—PLAN OF AN AMMONIA LOCOMOTIVE.

rear end of the locomotive. The outer tank is made in three sections (no great pressure is possible in it) on account of cheapness of construction, and it also allows of the raising off of the upper rounded section, or the intermediate, to examine or repair the inner tank, evaporator, or piping. The frame consists of two four-inch channel irons (twenty pounds per yard) nine feet long, which support the outer tank by means of cast-

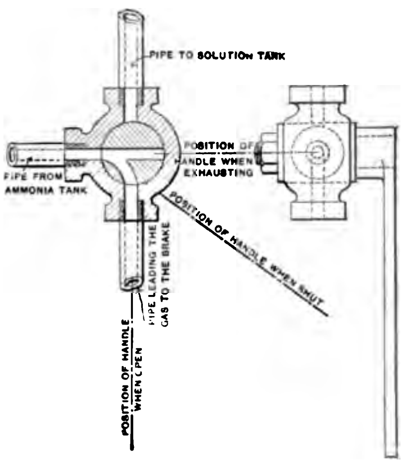


FIG. 5.—BRAKE VALVE.

iron suspenders bolted to the frame ; the jaws for the axle journal and the cylinders are also bolted to the frame. It is supported by equalizers connected by means of springs. The frame is twenty inches above the rail, with its full load.

The machinery consists of two six by nine-inch cylinders, with piston valves, surrounded by cast-iron jackets, the initial power behind the piston being 4,240 pounds. The piston works on a crosshead which is connected with the connecting rod to the driving wheel, and thence by means of a link rod to the front wheel. The piston valves are inside, and their rods are connected by means of rockshafts and levers with the reversing link, which latter are also inside. The brakes are worked by gas also, led through a three way cock or brake valve, to a three-inch cylinder, the piston of which works on the brake arms, and these on the shoes. When the gas is on, and it is desired to cut off the brakes, the gas returns through the valve to the solution tank, where it is at once absorbed. The brake shoes are hung in such a manner that they loosen when the gas is cut off. The gas trap, hung in front of the forward axle, is of one-eighth inch boiler iron, air and water tight.

The manner of operating the locomotive is as follows. The inner tank receives its charge, and the outer tank at the same time is filled with the 5 to 7 per cent. blow-off solution from the still, this solution being charged usually at a temperature of eighty degrees Fahrenheit, though a little more or less temperature does not matter : if above eighty it will give increased pressure ; if below, it will increase its heat in running by the discharge from the cylinders. The motor is now ready to run ; when its charges are exhausted, it returns to the station and they are renewed. The quantity of absorbing fluid in proportion to the anhydrous liquid charge is about five to one. When the liquid has been exhausted, it has been in the form of exhaust gas absorbed into the solution in the outer tank, which latter has practically become commercial ammonia, which, being withdrawn at the station, is redistilled and used over and over again, a new charge taking its place in the motor, as well as a new charge of anhydrous liquid. Thus the process repeats itself almost indefinitely, the annual loss being not over ten per cent.; from commercial ammonia to anhydrous ammonia gas, to anhydrous liquid, to gas, in this form used as a motive power, discharged then into water, which it converts into commercial ammonia. There is no reason why pure water should not be used, instead of the weak solution of ammonia from the blow-off, for absorbing ; this is, in fact, done, but the objects in using the blow-off solution from the still are obvious : first, the small percentage of ammonia therein is saved ; and, secondly, the temperature necessary for charging for proper operation could

not be more economically or easily obtained.

The economy of such a motor is easily understood: practically no loss of material, small amount of fuel consumed in the manufacture, the absence of a stoker on the motor, it requiring but one man to run it.

The exact cost of manufacturing anhydrous ammonia liquid has not yet been ascertained, nor the cost of operating; this will only come with time and experiment, but sufficient is known to state positively that the cost is not over one-fourth that of steam or any other motive force.

To revert again to the locomotive, the liquid force is as follows: it passes down from the inner tank into the evaporating tubes, and these, surrounded by the eighty degrees Fahrenheit solution, cause it to rapidly evaporate at a pressure of 147 pounds to the square inch. It rises from the manifolds at the ends of the tubes to the upper half ot the inner tank, from which it flows to operate the engines. The gas exhausted from the engine cylinders passes in at the bottom of the outer tank, at a point between the axles, and is instantly absorbed. A small pipe, leading from the gas reservoir, passes through the three way cock to the brake cylinder, and by simple means is returned into the solution of the outer tank.

The engine cylinders are surrounded by jackets, through which absorbing solution flows, for a two-fold reason; namely, to keep up an equitable expansion temperature, and to absorb any gas leakage that should occur.

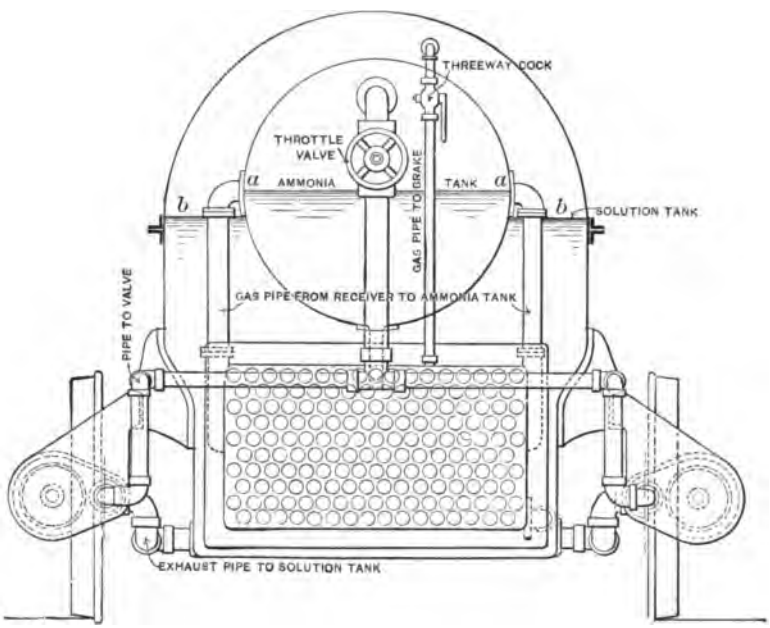


FIG. 6.—CROSS SECTION OF AMMONIA LOCOMOTIVE.

The object attained by the gas trap, which is about half full of water, which it is seldom necessary to renew, is to absorb through a check valve, by which it is connected with the outer tank, any gas not absorbed therein, avoiding thereby any possible back-pressure, smell, or leakage.

The discharge of the exhaust gas into the solution of the outer tank keeps the temperature of this solution almost constantly at eighty degrees Fahren-

heit, for reasons already given, the exception being that this discharge usually raises the temperature, the proof of which I have found to be, that a motor returning from a trip usually does so with its gauge showing a higher pressure than that with which it started out. Against this I find, that if from any cause an ammonia motor is allowed to stand, say on a siding all night, the temperature of the absorbing solution will fall materially. A simple means of raising its temperature, and the pressure as well, is to allow a small jet of ammonia gas from the reservoir to flow into the absorbing solution.

LEADING AMERICAN ENGINEERS.--JOHN BIRKINBINE.

By F. L. Biller.

THE name of Birkinbine is a familiar one in the engineering profession, two successive generations having been prominent in it. Mr. John Birkinbine, whose portrait appears in this number, is the eldest son of the late H. P. M. Birkinbine, who, during life, gained a wide reputation in the specialty of hydraulical engineering, and his two sons had ample opportunity to become conversant with field and office work in the profession which they both follow. During the ten years that his father was Chief Engineer of Philadelphia Water Department, much of the field engineering work was under the charge of Mr. John Birkinbine, including several hydrographic surveys of a portion of the Schuylkill River, reconnoissances to determine available sources of a water supply for the city of Philadelphia, and the detailed surveys and estimates for reservoirs and aqueduct, upon which the elder Birkinbine recommended the Perkiomen Creek as the source of supply for the city of Philadelphia. Associated with his father, and also for himself, he was connected with the designing and construction of numerous public water supplies, improvements of water powers, etc., and he continues as consulting engineer in these specialties for towns or companies, or as expert in water right suits.

One of the details of Mr. John Birkinbine's earlier water works constructions which attracted attention, was at South Bend, Indiana, where a wrought iron tube five feet in diameter and 200 feet long, weighing some twenty-two tons, was raised from a horizontal to a vertical position ; at the time that this was accomplished—in 1873—the feat attracted widespread notice. Among his later works is an elaborate report upon a comprehensive utilization of the great water power of the St. Louis River in Minnesota, close to the head of lake navigation, the power to be used locally or conveyed by wire to Duluth and Superior.

If early associations affect the inclinations of maturer life, the fact that at the time of Mr. Birkinbine's birth, his father operated a forge and auger works, near Reading, Pa., may account for a lively interest in metallurgy, a specialty in which he is recognized as an authority, not only in this but in foreign countries. He was educated in the public schools and the Friends High School, Philadelphia, and subsequently at the Hill School at Pottstown, Pa., and the Polytechnic College of Pennsylvania. Military service in 1863-4 and subsequent imperfection of the eyes interrupted his studies, and two years of apprenticeship in a machine shop resulted in a practical education of value to the young engineer. This practical work served him well, during his association with Mr.

P. L. Weimer in the firm of Weimer & Birkinbine, operating the Weimer Machine Works Company, at Lebanon, Pa., and since the works were incorporated as a company he has continued as a stockholder.

In February of this year Mr. Birkinbine retired from the presidency of the American Institute of Mining Engineers, after receiving as a testimonial of his executive ability, the unusual compliment of a re-election to the limit provided by the constitution of that association. He was active in the formation and served as Secretary of the United States Association of Charcoal Iron Workers, editing for nine years its journal. For a number of years he has been connected with the United States Geological Survey and is recognized as the Government expert upon iron ores. He also prepared the report on iron ores for the Eleventh Census; this report being one of the first to be completed, is generally recognized as especially valuable by reason of its business character, and absence of unnecessary technicalities.

While general manager of the South Mountain Mining and Iron Company, Mr. Birkinbine conducted a series of experiments upon the relative values of fuels for smelting purposes. Without stopping the furnace, the fuel charge was changed from charcoal to coke, from that to mixed anthracite and coke, then to all anthracite, back again to anthracite and coke, in varying proportions, and finally to charcoal again. The results of these interesting experiments were carefully compiled, have been published and liberally copied, and are referred to in works on metallurgy as being the most complete made.

Maintaining an engineering office in Philadelphia, which has been his home since childhood, Mr. Birkinbine has been called to most of the States, and to Canada and Mexico to examine and report upon iron ore mines, to advise upon the location of iron works, to design and construct new blast furnaces, or to remodel and rehabilitate older plants. He was the first American to critically examine and publish a report upon the noted Cerro de Mercado, at Durango, Mexico, visiting that locality in advance of the existing railways, and has lately returned from an extended trip in our sister Republic, the data which he collected being embodied in an exhaustive report prepared for English capitalists upon iron manufacture in Mexico. He was probably also the pioneer engineer to suggest the practicability of manufacturing iron on the great lakes by using coke made at the blast furnaces from coal brought from Pennsylvania. His report upon this subject resulted in the establishment of an iron and steel industry at the head of Lake Superior, and the modern blast furnace at West Duluth, Minnesota, was constructed from plans made by him and under his general supervision. Similarly, his report to the State authorities of Texas demonstrated the practicability of iron manufacture in that State, and resulted in an appropriation by the Legislature for carrying on this industry. As engineer, and in conjunction with Mr. E. S. Cook, the president of the company, who has done so much to advance the iron manufacturing interests, he remodelled the celebrated Warwick furnace, at Pottstown, Pa., and for a number of years was consulting engineer for the Philadelphia and Reading Coal and Iron Company.

Among the subjects to which Mr. Birkinbine has given special attention is the concentration of iron ore by magnetism, and in this specialty he acted as consulting engineer for Mr. Thomas A. Edison during his earlier experiments, and also for Messrs. Witherbee, Sherman & Co., of Port Henry, N. Y., making a series of practical tests of various machines, and assisting in the construction of concentrating works. For nearly a score of years Mr. Birkinbine has been active in the American Institute Mining Engineers, having been manager, vice-president and president, and having contributed liberally to its proceedings, his presidential addresses being particularly sought for. He is also a member of the American Society of Mechanical Engineers, of the Engi-

neers' Club of New York, the Manufacturers' Club, the Franklin Institute, and the Engineers' Club of Philadelphia, of which last he is now President. His contributions to the technical press are numerous and his various lectures before the Franklin Institute have appeared in the journal of that body.

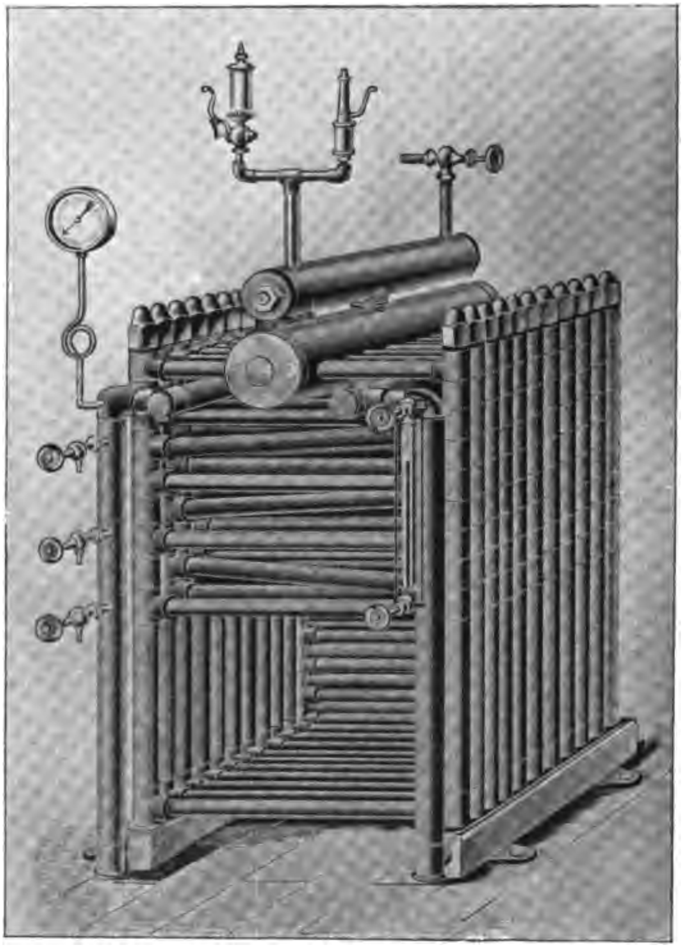
Mr. Birkinbine's reports upon properties and processes contain decided opinions, which are enhanced by his reputation for conservatism, a feature which has caused him to be called upon to value or appraise important properties, or to arbitrate in matters representing large amounts of money. In one instance, a claim for over $100,000 and a counter claim for nearly as much was by mutual agreement left solely to his decision, and his report was promptly accepted by both parties.

Practical experience in the manufacture of charcoal pig iron, impressed Mr. Birkinbine with the wasteful methods employed in all matters pertaining to our forests, and his education in hydraulics caused him to note the influence of denudation upon streams. It is, therefore, but natural that he should have been active in forming the Pennsylvania Forestry Association, the largest and most influential organization of the kind in the United States, and that he should be serving as President of the Association at a time when it accomplished the appointment of a State Forestry Commission, empowered to take up the problem of the propagation and preservation of forests and their influence on water ways for the entire State. During the six years of the Association's existence he also edited its publications.

THE BUCKLEY WATER TUBE BOILER.

IN connection with the descriptions in this number of the several water tube boilers shown at the World's Fair at Chicago, it may not be amiss to direct attention to what is known as the Buckley boiler, which is built by the Rochester Machine Tool Works, of Rochester, N. Y., and the main features of which are shown in the accompanying illustration. The boiler was specially designed for launch use, and strength, compactness and quick steaming capacity were, therefore, prominent factors to be considered in its construction, due attention also being given to the securing of a low centre of gravity.

The base pieces on which the whole boiler rests, as shown in the engraving, are of malleable iron, and have lugs on their bottom sides holding the nuts for the steel bolts which tie the boiler together. The individual boiler sections are of wrought iron or steel pipe with malleable iron fittings, and each row is connected with the one opposite by pipes inclining alternately at opposite angles. Running lengthwise, and somewhat below the level of the lower steam drum are two separator pipes into which the vertical boiler sections at the sides connect by means of short pipes just as they connect with the lower steam drum. The connections cannot be seen in the engraving, being hidden by other parts. Downtake pipes at the front and back of the boiler connect with the separator pipes, and carry the water back to the base of the boiler while the steam goes on through the section above into the lower steam drum. The latter consists of wrought iron pipe from four to six inches in diameter with steel heads secured with steel bolts. A second steam drum, arranged above the one just mentioned, helps to increase the steam room. On the rear end of the boiler there is also a pipe leading from the bottom of the lower steam drum directly back to the water base of the boiler, so that water, carried over into



THE BUCKLEY WATER TUBE BOILER.

the drum, is immediately returned to the water space.

All the joints are made with soft copper gaskets, and no left-hand threads are used on any of the fittings. Any part, it is stated, can be easily removed by an ordinary mechanic. The boiler can be built in a square form, or long and narrow to give ample passage way by it in a long and narrow launch. Oil, wood, coal or coke can be used as fuel. When coal or coke is used, a grate is employed that fits on top of the lower water pipes. The boiler was approved by the U. S. Government for use in yachts, on Government waters, in April, 1893.

It is, at present, built in sizes of from three to six horse-power, but larger sizes are soon to follow.

ANDREW JAMIESON.

CASSIER'S MAGAZINE.

VOL. IV. SEPTEMBER, 1893. No. 23.

COPPER MINING IN NEVADA.

By Ernest V. Clemens, Mem. Am. Soc. M. E., Mem. Am. Soc. C. E.

"ON SING."

A TRAVELER commenting on the 71,737,600 acres occupying a portion of the Northwestern section of the great basin and which is inclosed in the Nevada boundary lines, compared it favorably with the infernal regions, adding that with certain local improvements such as water and good society the conditions conducive to healthful habitation would be equally enhanced in either case. The steady decline in the value of silver, together with the present uncertainty of its future, has perhaps been a wholesome affliction to those portions of the country which, though possessed of unquestioned wealth in other minerals, yet have been searched only for those which represented to the miner or prospector the greatest value in the smallest bulk. The Nevada contingent of the prospecting fraternity accepted the situation with commendable philosophy, and is now vigorously at work opening the copper, nickel and antimony mines of the State which have heretofore been practically unnoticed. Unfortunately for Nevada the railroad to which her commerce is subject, is the only one which traverses the State and it is the territory contiguous to this railroad upon which the trans-continental traveler or tourist bases his opinion of the State as a whole. The expressed verdict of those who see and know of Nevada only from views within range of the eye taken from Central Pacific car windows while rushing along at a thirty or forty mile pace is usually "arid territory," "barren waste," "decomposed granite," "alkali desert," "sage brush," etc., and is true in part, and therefore pardonable, though erroneous in its greater sense. It is obvious that the arid acres void of water and vegetation are not habitable, just as it is true of the marshes and swamps of the more populous States, and what private capital with government and State aid has accomplished in draining and reclaiming the latter will, as our national population increases, be consummated in the former by artesian wells and irrigation. One need but read the 1892 report of Nevada's Surveyor-General, Mr. John E. Jones, to be convinced that the returns to the agriculturist and horticulturist in the sage brush counties of Nevada, when irrigated, exceed those of almost every other part of the country. Four hundred bushels of potatoes per acre of irrigated ground

is but one item of the Surveyor-General's report which illustrates the plausibility of the foregoing, with the request from the editor of the magazine, for the present article was the suggestion that it be devoted entirely to an account of the prospector and miner of Nevada, together with a description of the Copper mines now being developed in Churchill county, but the temptation to offer a word that might dispel the prevailing idea that Nevada has only mineral resources to offer as inducement to the settler has been yielded to. Opinions formulated through a wider acquaintance made by traversing her interior by stage and "Cayuse," are obviously more in accordance with fact than those derived through observations obtainable from a single route traversing the State from east to west, and which was chosen not by the artist, the farmer, the miner, or the settler, but by the civil engineer who sought less for the interest of the State than he did to build the link connecting the Atlantic with the Pacific at a minimum cost per mile.

It is, however, due entirely to her mineral resources and the undying devotion of the prospector to his vocation that Nevada is known to fame. Decades prior to the completion of her railroad, the State was famous owing to her fabulous deposits of the precious metals ; it was then that such men as the prospector, shown in one of the illustrations, left comfortable homes and gambled their time in tireless search against the chances of a "strike." Long years spent in "roughing it," and isolation from centres of civilization, made their exteriors ungraceful perhaps, and their language uncouth though unique, but their high appreciation of the unwritten laws of the mountains in justice of man to man and their ever readiness to assist and care for an unfortunate brother, stamp them as men of sterling worth and character. Prospectors are first and last Americans. If their patriotism is expressed with lack of refinement it is nevertheless of a superior quality for occasions when national complications are beyond amicable adjustment by the polished diplomats and wise men of the East. If they use the product of their lead mines to execute their wholesome unwritten laws and to express their disapproval of horse stealing, they simul-

TWO TYPICAL PROSPECTORS, LOVELOCK AND KELLOGG.

MRS. PIERGUE, THE BELLE OF THE CAMP.

taneously therewith decrease the danger to posterity of inherited criminality.

It was due to the discoveries by just such men as the two prospectors whose portraits are shown in the illustration on another page, Lovelock and Kellogg, that the Comstock lode bonanzas are famous the world over. Just such men became millionaires, who prior to their fortunate "find" wore just such apparel, drank from a tin can and when overtaken by night on the mountains, rolled themselves in a buffalo skin or blanket and laid with their guns convenient to interrupt the barkings of a too familiar wolf, with not even a tent to prevent their counting the stars from horizon to horizon when the excitement of the day's "find" of "ledge matter," rendered the darkness vexatious and sleep impossible.

Since the prospectors' location of the Comstock mines, $600,000,000 have been extracted from them and poured into the nation's horn of plenty. The Mackey-Bennett cable, the Postal telegraph, hundreds of regal monuments in the large cities of the country, the Mills building, New York. Such hotels as the Palace, the Baldwin, the Grand Opera House and the new California theatre in San Francisco ; palatial residences by the score, whose immensity, grandeur and architectural grace are of universal admiration ; steamships, railroads, newspapers and development of innumerable engineering and commercial enterprises in sister States, all of which owe their possibility to this fraction of Nevada's hidden resources, attest to the zeal of her prospector citizens in combination with the inevitable pick, such as the one fastened to the hand of one of the subjects illustrated by the push of a kodak button.

Immense deposits and veins of nickel, cobalt and copper in the Buena Vista mountains have long been known to the prospector, but those metals were not in his category of wants. It was mines of gold and silver that carried their more fortunate companions to fortune and fame; therefore they sought

A ROAD TO THE MINE.

INTERIOR OF A SMELTER.

and worshipped the deities which they believed could alone furnish them with the sensations to be experienced in removing their families from the "dug out" on the mountain side to a palace on Nob Hill.

The nickel mines which have been developed proved to be the most extensive and richest in the world. Forty thousand dollars from the White Cloud Copper Mining Company is Lovelock's return for his copper claims, and many others begin to realize that there are now other fields than gold and silver to reward their investigations.

A TYPICAL SMELTER.

Less than a year ago there was naught of civilization within thirty-eight miles of the prospecting cabin located on the Western foot hills of the Buena Vista mountains, in Churchill county, Nevada, within a stone's throw of the old overland trail, and one mile from the sand hills which border the Carson desert. To-day a thriving mining town exists, as mining towns go, where substantial buildings have been and are being built, and all the accompaniment and followers of a progressive and substantial mining camp have changed the scene. The tortuous trails which led from the mouth of Hitchcock cañon to the mines, and which were in many places difficult of passage, even to the pack mule, are substituted with broad roads and wire rope tramway. The stream which pilots the melted snows from the mountains to the desert below has been intercepted and its waters piped to the smelter and to the town for the benefit of the horses and mules, and the slant-eyed Mongolians, who use it for cooking and laundry purposes. Liberal drinking, if not a liberal science, is liberally indulged in by the Nevada miner, and is perhaps due to the altitude and exceedingly dry atmosphere, yet his thirst rarely drives him to water, and it is safe to state that any one of the saloon keepers of this

READY FOR LUNCH.

THE TOWN AT SUNRISE.

camp receives on an average per month per customer ten times that of the elegantly appointed beverage dispensaries of the large cities.

The view of a portion of the town, shown in the illustration, was taken at sunrise, and shows a cloud just striking the mountains above. It is a frequent occurrence with the miners to find themselves in sunshine with a blanket of white clouds hundreds of feet below them and completely shutting off the view below. The scene as the clouds gradually encircle the mountains—and it will frequently transpire within a few moments—is grand to behold. While beautiful, it is one of great concern to the prospector when the mountains are deep with snow and such clouds have obliterated his landmarks.

Squatter sovereignty is most grotesquely exemplified by some of the miner's cabins set in snug nooks of the cañon, such as represented in the canvas cabin of two adventurous people, Mr. and Mrs. Joseph Piergue, at what is designated as the upper camp, and which was described by a Lancashire machinist as "a calico tent weer the folks kept warm by shufflin' cards and drinkin' grog."

In a mining camp, as anywhere else, one meets all kinds of people. Mrs. Piergue, who stands on the lawn in the foreground in one of the illustrations, claims by virtue of an old Dutch deed and as a descendant of ex-President John C. Fremont, to be an heir to millions, in the form of forty acres of real estate in New York city, bordering the East river and Hell Gate, where are located the Ruppert and Ehret breweries. Proofs of identity and lawful ownership were minutely explained to the writer, and an offer extended of one-half the plunder should he take up her case and conclude it in successful issue. Only those who have experienced the cruel awakening by the fall of high built hopes, after being

A STONE CABIN.

ONE OF THE TRAILS.

drugged with sensation of transient gleams and dreamy cadences contingent to expectations of sudden elevation to independence, could appreciate my despair or tone of voice, as I explained to her that her ancient Dutch patent was issued in days so remote that Manhattan Island was governed by persons of foreign birth who were not in touch with sympathies of to-day, and efforts to recover would consequently be a non-suit, with costs to plaintiff. With a philosophy born of mountain grit, she remarked that she had "got along so far without it" and "sposed" she could "stick it out."

The group of miners just out of the "Stone Cabin" mine, for the midday lunch, are a typical lot of the good-natured, easy going characters, that work for good wages until they have accumulated a balance equivalent to the expenses of a prospecting trip. Then usually they leave for a journey, to locate such "cropping" that their picks have brought to light, one-half interest in which, in case his expenses were paid by others, usually goes to those who furnished the "grub stake," as it is called.

Mr. Barnett, who is the superintendent of the White Cloud Copper Mining Company, in Churchill county, never tires in praising the good qualities of these prospector miners. Their only failing, he says, is in frequently leaving their whole month's earning at the saloons in a single night. With no other entertainment to attract their evening attention, they assemble there to exchange experiences of the day and incidentally to play the typical American game, "poker," and relieve themselves of surplus wealth and such yarns as the topic of conversation may remind them.

The individuals comprising this mountain fraternity are from all parts of the Union, as well as from foreign countries, many of them being men of rare education. Mechanics of ability, and occasionally a man with a profession, and ex-merchants, but the greater number may be enumerated among the countless numbers of unfortunate mortals who have chased delusive dreams of easily acquired fortunes to the mining fields and there became "strapped." It may be pride which continues to exile them from home and family, otherwise the inherent anticipation to realize on their golden hopes is responsible for their continued sojourn in the mountains, and though all claiming to be regular miners, emergencies will find available among them barbers, tailors, shoemakers, carpenters, machinists,

butchers, jewelers, as well as occasionally an actor.

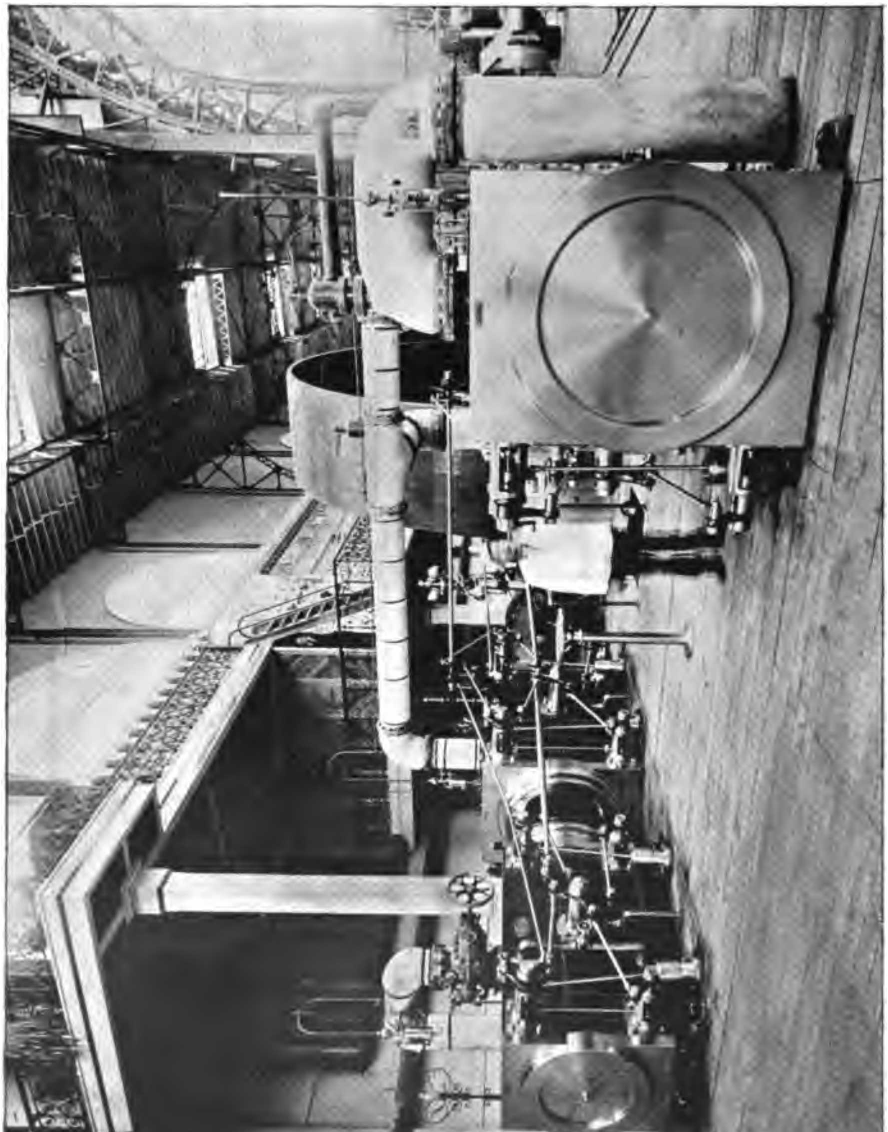
The first smelter run successfully terminated within the past month in the smelter building illustrated, has demonstrated conclusively the great value of the extensive ore properties and the miners of the mining company previously mentioned, who have located claims in the surrounding hills, are enthusiastic over their prospects, and the probability of a solid town to be anchored in Churchill county and near the celebrated mineral deposits.

A MINER'S DWELLING.

Sample assays of their "Red Oxide" mine ores have analyzed 60.62 per cent. and 47.50 ounces of silver. Their "Carbonate" mine first-class ores assay twenty per cent. copper, and "Stone Cabin" mine ores (chalcopyrite) first-class, from thirty per cent. to forty per cent. copper, with silver contents sufficient to pay mining and smelting expenses of that ore. The ores are self fluxing and easily converted to sixty per cent. copper mattes. Seven hundred pounds of pure pyrites was used to the ton of charge, and the successful elimination of sulphur from the matte speaks highly of the superintendent's work, as it does for the exceptional qualities of the ores charged with the pyrites.

The White Cloud Company have expended about $100,000 for mines and in building roads, tramway, smelter, large eating and sleeping houses for miners, store, office and assay buildings, etc., and have at time of this writing about 100 employees, whose outer and inner conditions are well cared for by Chinese laundrymen and cooks, such as Ong Sing, whose culinary accomplishments have made him a great favorite in the "camp."

The mining and working of copper ores marks the dawn of a new era in Nevada's history, and if the sequel is in keeping with initiatory experience at the new town of Clemens, silver and gold will in a few years occupy other than first place in the reports of mineral productions by the Surveyor-General of Nevada.



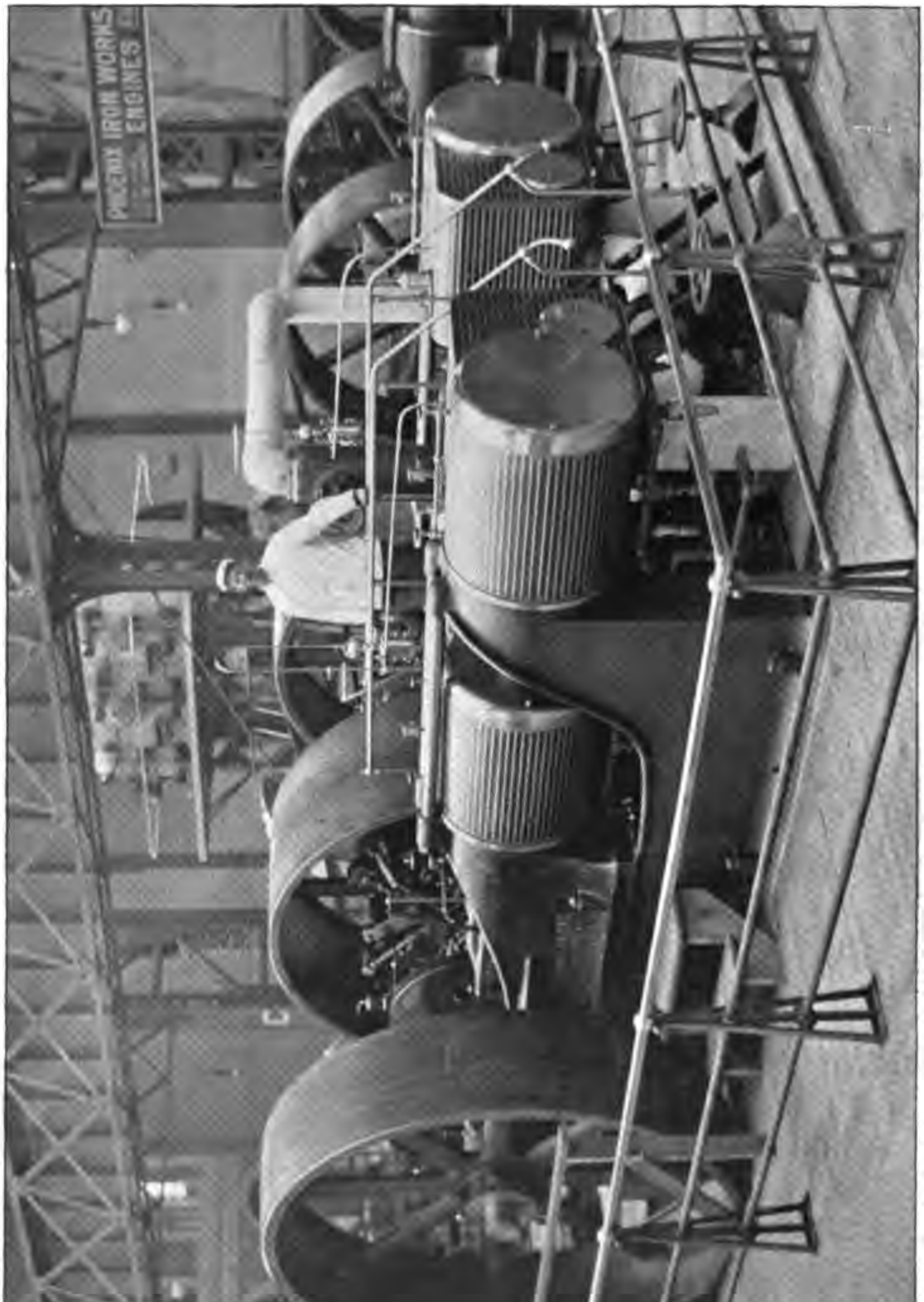
STEAM ENGINES AT THE WORLD'S FAIR.—ONE-THOUSAND HORSE-POWER TRIPLE-EXPANSION ENGINE
BUILT BY FRASER & CHALMERS, CHICAGO, ILL.

STEAM ENGINES AT THE WORLD'S FAIR.—IV.

By Geo. L. Clark.

AN interesting and most valuable outcome of the steam engine exhibit at the Fair will probably be found in the results of the series of tests which it has been proposed to make in connection with a number of the engines. Among these will be, to begin with, the quadruple expansion Allis engine referred to in the first of these papers. This engine represents probably the most advanced design in the steam engine line and, as pointed out by the sub-committee of jurors having the proposed trials in hand, no public determination of the possibilities of such an engine as to economy has been made up to the present time. It will, therefore, be eminently consistent with the educational interest of the Exposition that a careful and thorough investigation of its performance be instituted. The next engine to be considered in the trials would be that built by Messrs. Fraser & Chalmers of Chicago, and described further on, the engine being a representative example of a modern, triple-expansion engine of the Corliss slow-speed type. The Buckeye triple expansion engine, described in the May number of this magazine, would also be tested as an example of a two-valve engine with a shaft governor. Further, the German engine, exhibited by E. Schichau, also previously described, and belonging to the vertical, triple-expansion type, would be tried as an example of foreign, continental practice, while the Galloways compound engine would be taken as a representative English design. A vertical Allis engine, remaining to be described, would follow in the list, embodying a novel principle calculated to give economy under variable loads. This principle lies in the valve gear, which is operated so as to preserve a fixed initial pressure and cut-off, whatever the amount of load. Whenever the load is less than that corresponding to this cut-off, the resulting increase of speed causes the governor to shut off altogether the supply of steam, and, as in some gas engines, no further admission occurs until a reduction of the speed below the normal causes the governor again to open the admission valve. The novelty of this principle is thought sufficient to warrant a test, and it would be made in a series covering several loads. Next would come the Westinghouse steeple-compound, double-acting engine, illustrated and described in this number, one of the features of which consists in the use of a large clearance volume in the high pressure cylinder, so as to restrict the range of pressure and temperature during expansion. Tests would also be made of the 500 horse-power Ball compound engine, as representative of one class of high-speed, automatic engine of the common type; of a Willans vertical compound engine of English make; and of a number of others not yet particularly specified.

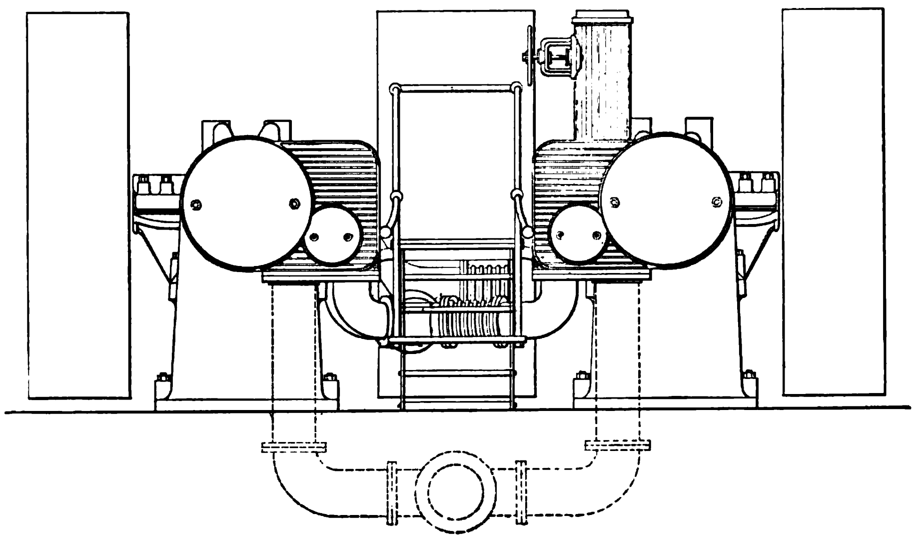
Of the Fraser & Chalmers engine, referred to in this list, a general view is given on the opposite page. The engine, which is rated at 1000 horse-power and runs at a speed of 64 revolutions per minute, is of the four-cylinder, triple expansion design, having one high-pressure cylinder, 20 inches in diameter; one intermediate cylinder, 34 inches in diameter; and two low-press-



FOUR-CYLINDER, TRIPLE-EXPANSION "DICK & CHURCH" ENGINE, BUILT BY THE PHŒNIX IRON WORKS CO., MEADVILLE, PA.

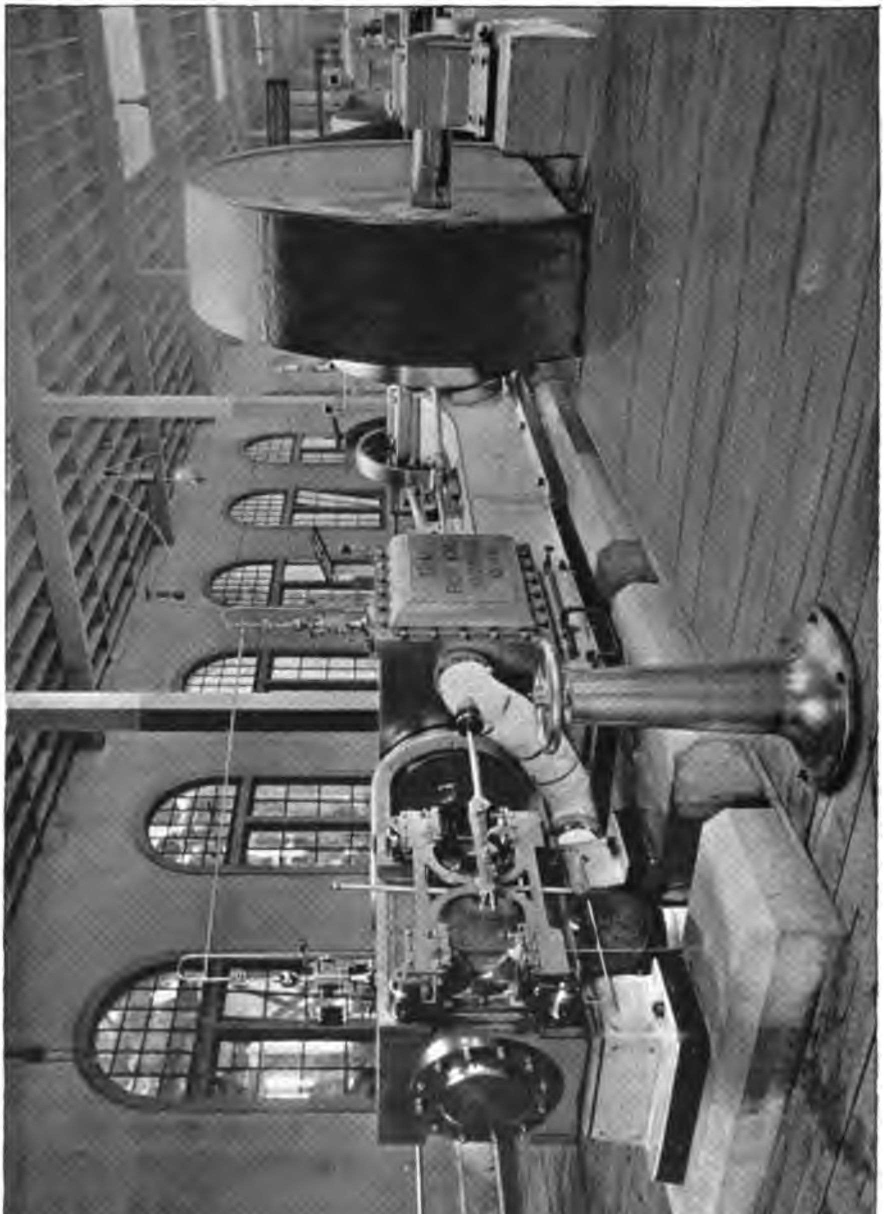
ure cylinders, each 34 inches in diameter, the stroke of all being 60 inches. The purpose of this arrangement of cylinders is, of course, to equalize the turning moment and the strains and power exerted on each crank as far as possible. All the cylinders are steam jacketed on the heads as well as on the sides.

The valve gear is of the regular Fraser & Chalmers Corliss type. The cut-off gear of the high-pressure cylinder is always under control of the governor, but the novelty appears in the cut-off gears of the remaining cylinders. If there are no sudden changes of load, the cut-off should be constant in the other cylinders in order to secure a uniform, minimum drop of power between these cylinders, the cut-off depending upon the size of the receiver and cylinders; but if the load were suddenly and largely reduced there might remain steam enough in the receivers to cause the engine to speed up or run away even if all the steam were cut off from the high-pressure cylinder. On the other hand also, with the sudden imposition of a great increase of load the increased admission of steam in the high-pressure cylinder might not be sufficient to maintain the speed of the engine. To guard against these contingencies the cut-offs of the intermediate and low-pressure cylinders are connected with the governors by means of oil cataracts. A slow motion of the governor will not affect the intermediate or low-pressure cylinders, the cut-off cams being held in position by springs; but any sudden motion of the governor transfers itself instantly to the cut-off cams, which, after this influence has passed, again slowly recede to their normal position. In short, the cut-offs of the intermediate and low-pressure cylinders are changed only in cases of emergency, and not long enough to reduce the economy of the engine. The connecting pieces between the cylinders are made in halves so that they may be taken apart for convenience in examining cylinders and pistons. The engine is of course used condensing, but the condenser in this case is not of the Fraser & Chalmers design, but one furnished by the Conover Manufacturing Company of New York, for exhibition in connection with this engine.



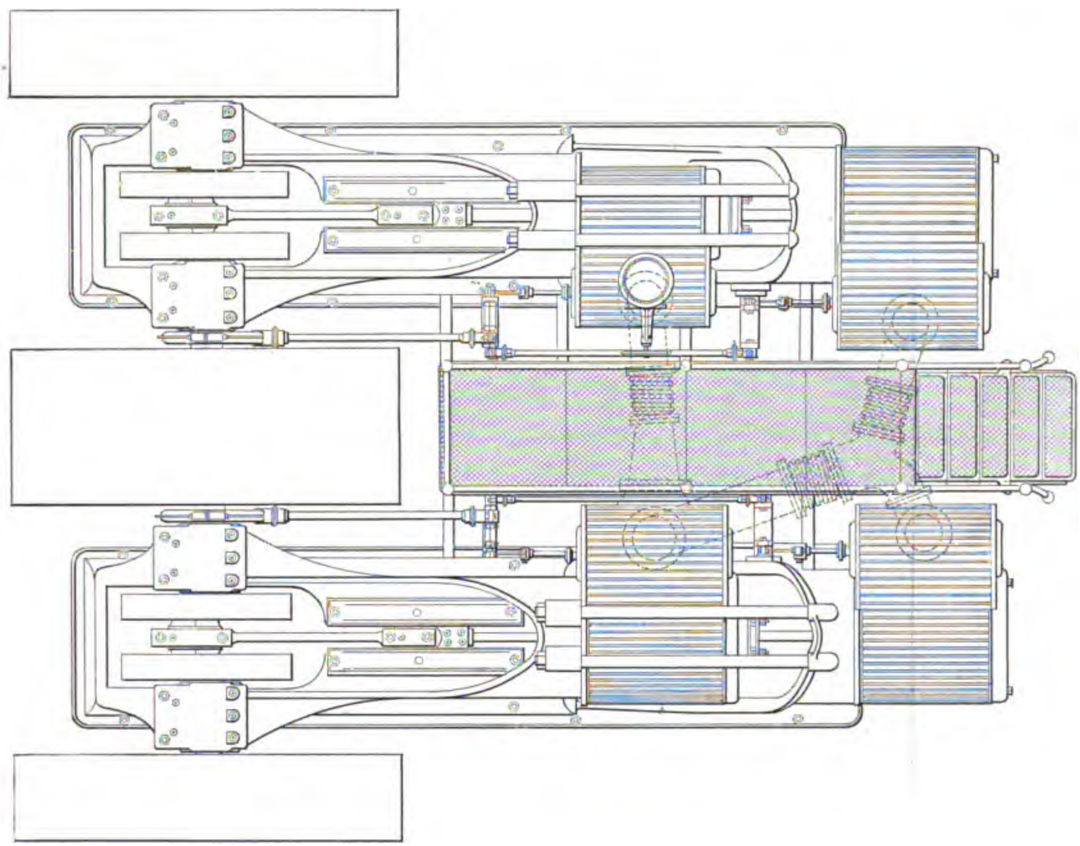
END VIEW OF THE "DICK & CHURCH" ENGINE.

One of the most attractive and novel engines on exhibition is the "Dick &



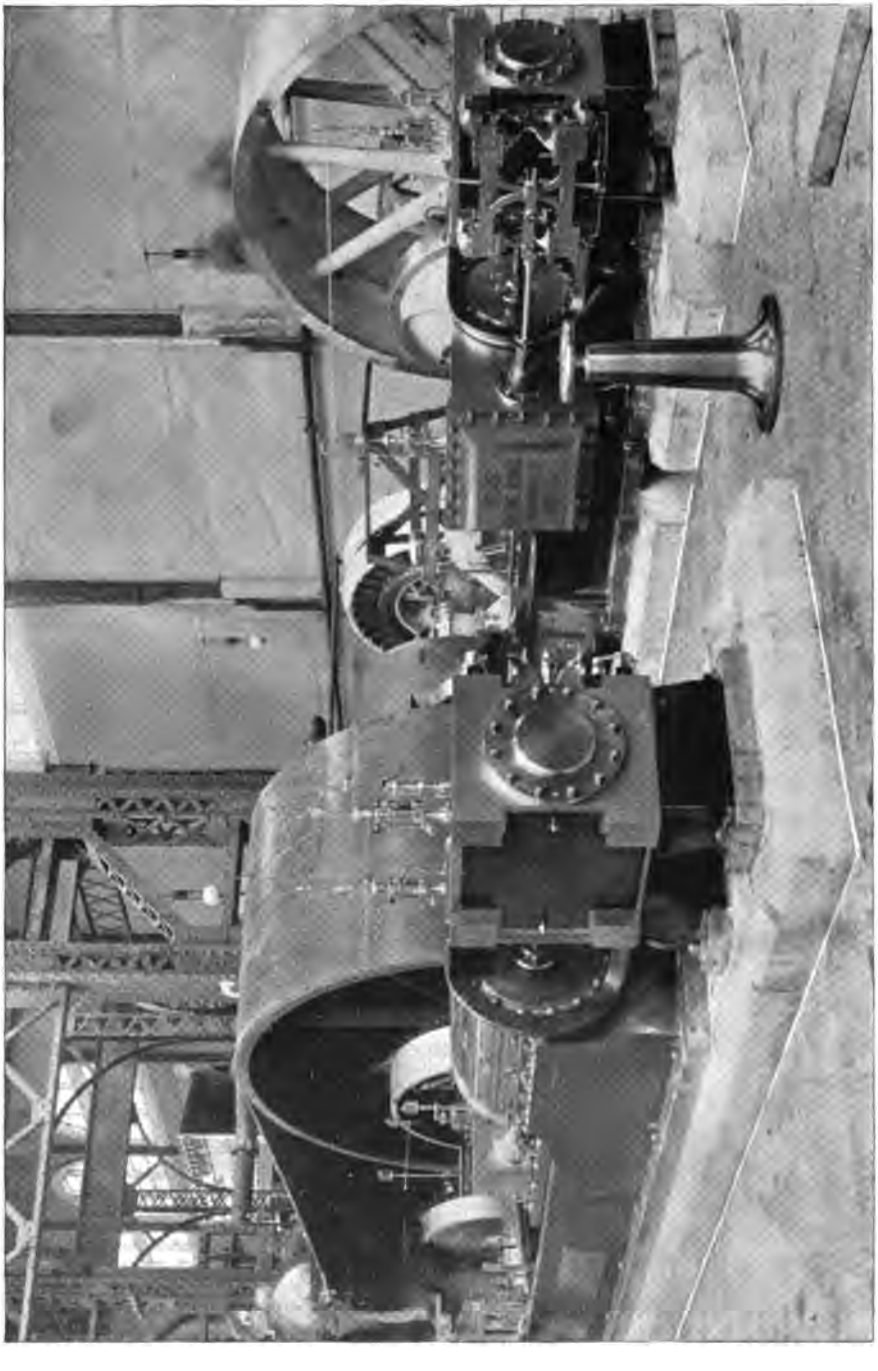
TANDEM COMPOUND ENGINE, BUILT BY THE ATLAS ENGINE WORKS, INDIANAPOLIS, IND.

Church" four-cylinder triple-expansion engine of the double tandem, cross-compound type, built by the Phœnix Iron Works Company, of Meadville, Pa. This engine is substantially a combination of two of their tandem-compound engines, illustrated in the May number of this magazine, and the description which was there given applies largely of the engine has substantially the same valve gear as the regular tandem compound engine, and the governor is also substantially the same. This valve gear is placed on the inside. The governor is made double and is placed in the intermediate wheel. It is so cross-connected that the two sides of the engine are compelled to act together,



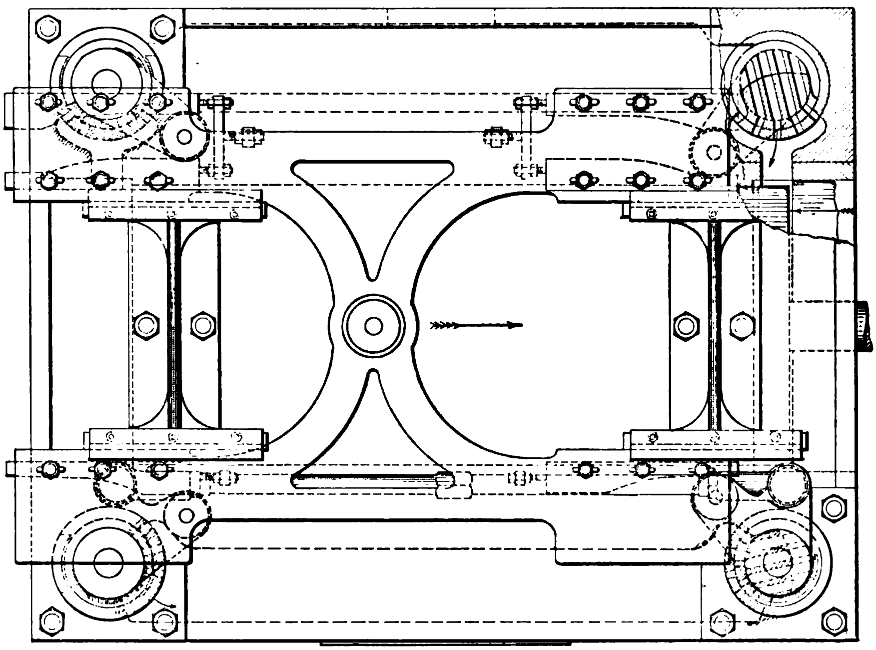
PLAN OF THE "DICK & CHURCH" ENGINE.

to the general features of each side of the present design, with the exception that on one side the intermediate cylinder is substituted for the high-pressure cylinder of the regular tandem engine, being secured to the small, or high-pressure bed. The two low-pressure cylinders are placed in the rear, each being carried on a sub-bed. Each side the one governor controlling the valves of all four cylinders, thus insuring close regulation and the proper distribution of load, temperatures and initial thrusts throughout the whole range from friction load to full load. The steam passes from the high-pressure cylinder to the intermediate cylinder on the opposite side, and from this cylinder it is carried



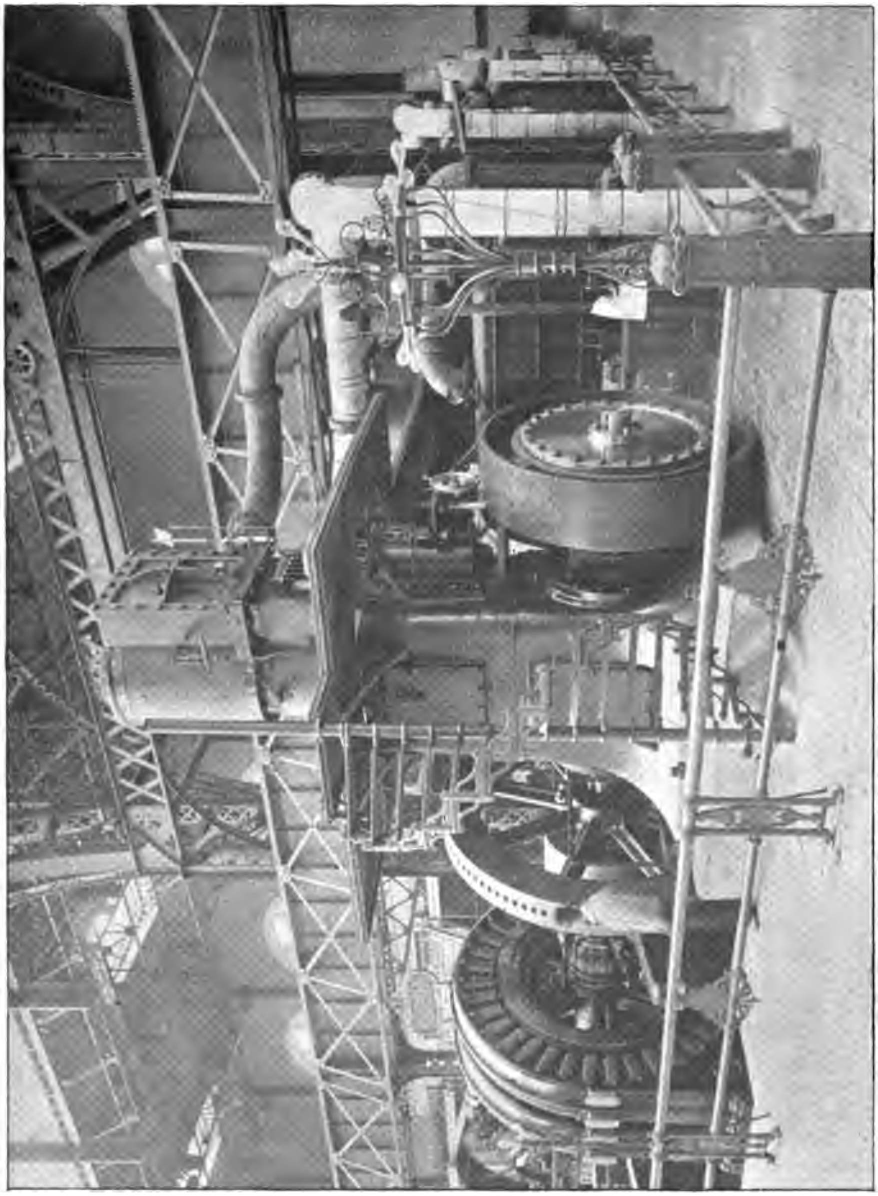
DOUBLE, TANDEM-COMPOUND ATLAS ENGINE.

by a branched pipe to both of the low-pressure cylinders. These intermediate pipes are connected with the under side of each steam chest, and are kept as high as practicable to prevent the formation of dangerous water traps between cylinders. A neat platform, with steps at the rear, is placed between the engines and over the intermediate pipes. This gives ready and convenient cylinder heads and intermediate pipes have non-conducting coverings, with metal outside lagging. The two sides of the engine are placed close together, but at the same time ample space is provided for all the parts and easy access to all of them. That the engine is compactly built is evident from the fact that, although rated at 525 horse-power, with a maximum capacity of 750 horse-



VALVE GEAR DETAIL OF THE ATLAS ENGINE.

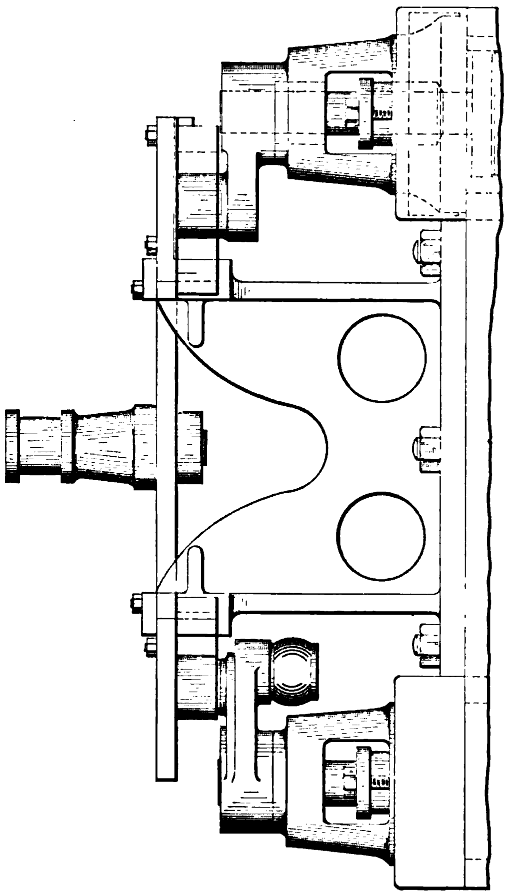
access to the valve gear, crosshead and guides, throttle valve and other parts, and two oil cups, one on each front corner post of the platform railing with pipes leading to all the parts requiring lubrication, including the eccentrics and the pins and bearings of the governor, enable the engineer to keep all working parts thoroughly lubricated while the engine is in motion. The observer cannot fail to note that the cross-connected intermediate pipes, which in most cross-connected engines are such a disfigurement, as well as an obstruction, are entirely hidden by the platform. The cylinders, steam chests, power, it only occupies a floor space of 17 feet 8 inches in width, by 27 feet 7 inches in length, measured clear of the wheels. The high-pressure cylinder is 15 inches in diameter; the intermediate, 24 inches, and the two low-pressure cylinders each measure 26 inches, while the stroke of all is 18 inches. The wheels are 108 inches in diameter, the two outside ones having 26-inch faces, while the centre one has a 38-inch face. The working speed is 200 revolutions per minute. The engine presents a graceful appearance, at the same time impressing the observer with a sense of its massiveness and the great



STEEPLE COMPOUND, DOUBLE-ACTING ENGINE, BUILT BY THE WESTINGHOUSE MACHINE CO., PITTSBURGH, PA.

amount of power stored in such compact space, coupled with extreme simplicity of construction.

Two engines are exhibited by the Atlas Engine Works of Indianapolis, Ind., one of them representing a single and the other a double, tandem-compound design. The cylinder dimensions are the same in each, 14 x 24



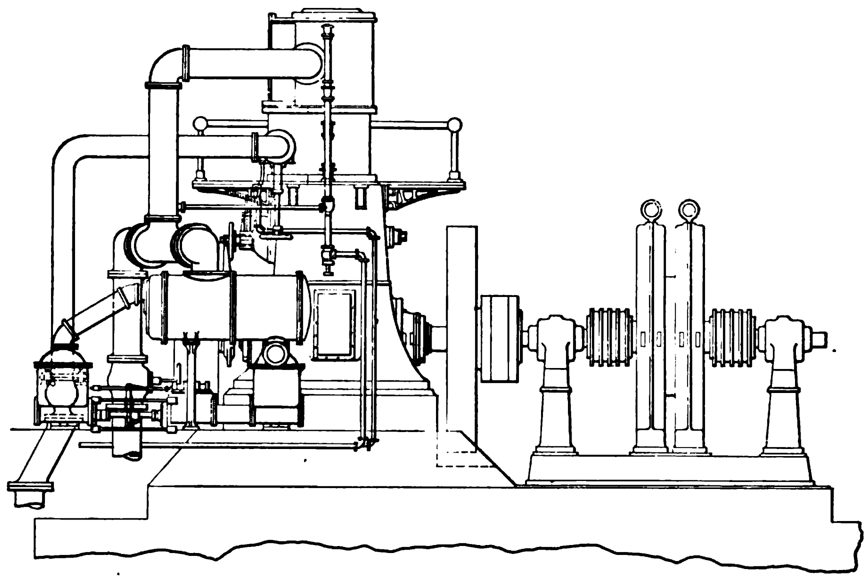
VALVE GEAR DETAIL OF THE ATLAS ENGINE.

inches, with 30-inch strokes. Both engines are designed to run at 150 revolutions per minute, the single tandem-compound engine driving ten 50-light Thomson-Houston dynamos, while the double engine is connected to one of the large Westinghouse, 10,000-light incandescent dynamos, their rating being 500 and 1000 horse-power respectively. With the exception of the high-pressure cylinders, these engines are samples of the single valve automatic heavy duty engine which the makers have been building for several years. This engine has several notable features, among which are the massive bed-plate, the main bearing, with removable boxes, the peculiar form of cross-heads and the automatic dead wheel governor. This governor, like those of other builders, controls the engine by changing the throw and angular advance of the eccentric, but is so arranged that the action of the weights and springs is reinforced by the inertia of a heavy loose wheel, which gives it unusual power. The valve is a flat slide perforated by steam and exhaust ports, and relieved from pressure by a massive pressure plate. To meet the demand for engines of higher efficiency, the builders have compounded these engines, by adding high-pressure cylinders. These are of the four-valve type, there being separate steam and exhaust valves for each end. The cylinders are supported by feet on the foundations at the back of the single valve cylinders, which serve as the low-pressure cylinders. The high and low-pressure cylinders are connected by a distance piece so designed as to permit the removal of both cylinder heads and pistons without disturbing the connection.

The striking feature about the high-pressure cylinders is found in the valve gear, which is of a novel and unusual kind. The rather high speed at which the engines were designed to run, of course, precluded the use of the regular Corliss, or any form of releasing valve gear. The designer was, therefore, compelled to devise a positive motion which would accomplish the same results and be unaffected by the speed. This he has succeeded in doing in a very simple and effective manner. The valves are of a form for which the builders obtained a patent several years ago. They are like the Corliss, except that, like the seats, they are provided with a number of ports. This gives them the property of the well-known

gridiron valve. The valve seats are sleeves or bushings forced into bored holes in the cylinder, and are removable when worn or injured. The ports are cut in the valves and seats by an index milling machine, so that perfect correspondence is secured. At the same time, on the outer ends of the valve and seat, the ports are marked with the cutter, which affords a convenient and accurate means of ascertaining the set of the valves when the covering bonnet is removed.

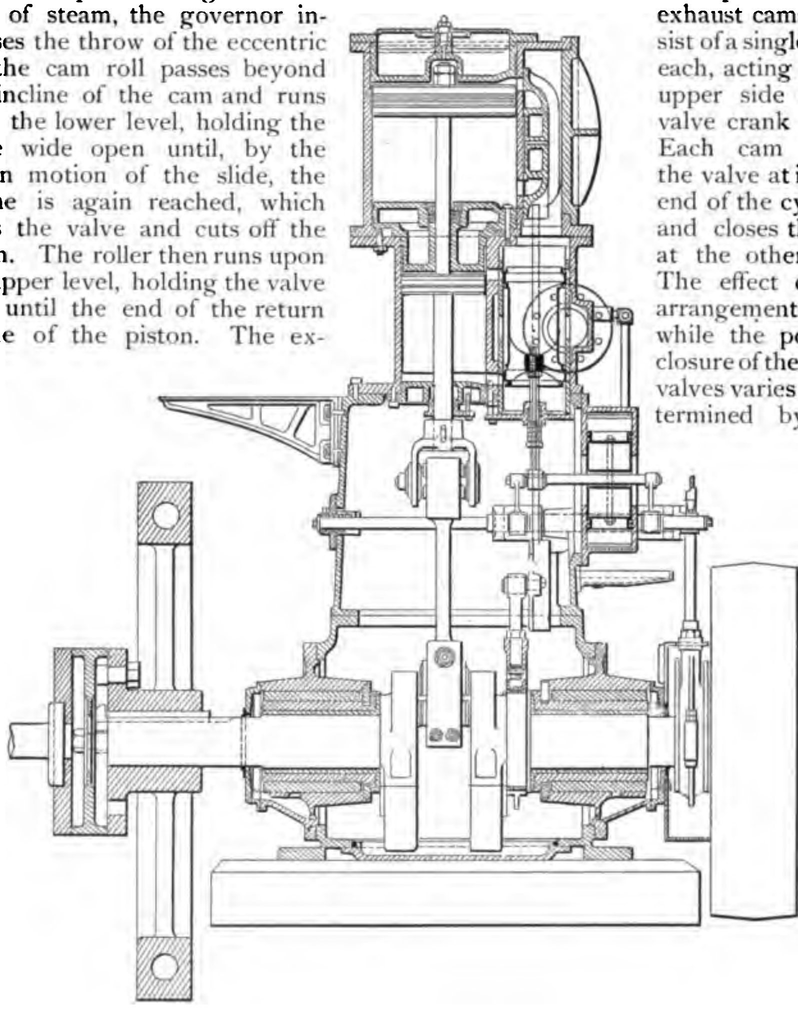
The valves have stems and supporting bonnets like in the Corliss arrangement, but instead of the usual catch blocks on the valve stem cranks, the crank pins carry steel cam rollers, about 2¼ inches in diameter by 1½-inch face, on anti-friction roller bearings. Instead of the Corliss wrist plate, there is a sliding piece supported by brackets on the cylinder between the valve bonnets. The stem of the low-pressure valve is prolonged through a stuffing box at the back of the steam chest and connects by means of a drop latch with a wrist on the sliding piece. This gives the sliding piece, when the engine is running, a reciprocating motion variable in extent with the throw of the eccentric of the shaft governor. On the sliding piece is mounted a set of cams which engage the rollers of the valve cranks and operate the valves. The cams are fastened to the sliding piece by bolts passing through slotted holes which permit their adjustment. The steam valve cams are made in two parts so placed with reference to each other as to form a groove embracing the roller on the valve crank. This groove has two level portions joined by an incline.



END ELEVATION OF THE WESTINGHOUSE STEEPLE-COMPOUND ENGINE COUPLED TO DYNAMO.

Into the ends of the two parts of the cam are screwed studs connecting them by a yoke, the stem of which passes through a lug on the sliding piece. The nuts on the studs permit adjustment of the two parts of the cam to take up lost motion, and the nuts on the yoke stem provide for adjusting the whole cam when setting the valves. The motion of the cam slide is such that at the end of a stroke of the piston, the cam roller is just at the top of the incline of the cam groove. While the engine is passing the centre, the cam slide moves far enough to carry the

roller down the incline and to open the valve. When cutting off at the shortest point, the cam slide moves only far enough to give the valve its full opening, and the eccentric, passing its centre, reverses the motion of the slide and immediately closes the valve. When the load requires a longer admission of steam, the governor increases the throw of the eccentric and the cam roll passes beyond the incline of the cam and runs upon the lower level, holding the valve wide open until, by the return motion of the slide, the incline is again reached, which shuts the valve and cuts off the steam. The roller then runs upon the upper level, holding the valve shut until the end of the return stroke of the piston. The exhaust valve cranks are double-armed, one arm of each carrying a cam roller and the other two being connected by a parallel rod, which compels the pair of valves to move together. The opening of one valve shuts the other. The length of the parallel rod may be adjusted by means of right and left threads at the ends, so that the lap of each valve is greatest on the closing side. The effect of this is to close one valve just before the other opens, and the compression and release may by this means be made to occur at the desired points. The exhaust cams consist of a single piece each, acting on the upper side of the valve crank roller. Each cam opens the valve at its own end of the cylinder and closes the one at the other end. The effect of this arrangement is that while the point of closure of the steam valves varies as determined by the governor, the exhaust valves, though operated by the same eccentric, have a uniform motion, opening and closing at the end of each piston stroke. Indicator cards taken from one of these engines show the distribution of steam to be nearly perfect. By means of the



VERTICAL SECTION OF THE WESTINGHOUSE STEEPLE-COMPOUND ENGINE.

drop-latch the cam slide may be disconnected from the eccentric, and a starting bar is provided by means of which the valves may be worked by hand to back the engine off the centre in starting. The whole arrangement is neat in appearance and noiseless in action.

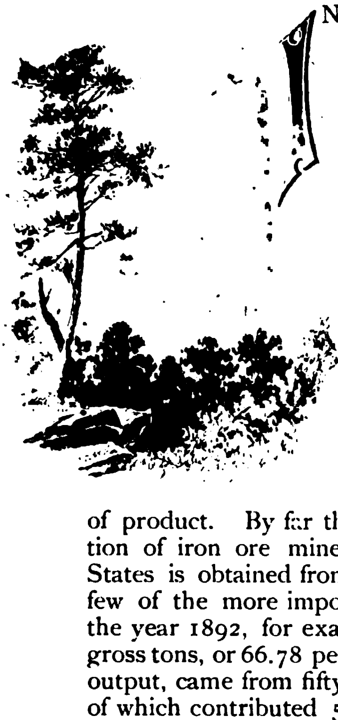
While the Westinghouse Machine Company of Pittsburgh have at the Fair a number of their well-known "Junior," "Standard" and regular compound engines, the chief interest of their exhibit lies in six steeple-compound engines of an entirely new type recently developed by them, the engines being double and not single-acting like the other Westinghouse engines, and each being rated at 1000 horse-power, which is the smallest size of this type to be turned out. The general and sectional views and the end elevation of one of these engines which accompany this paper clearly explain the main features of the design. The low-pressure cylinder is mounted above the high-pressure cylinder and has a flat slide valve. The high-pressure valve, on the other hand, is of the piston type, and the exhaust from the lower end of the high-pressure cylinder passes up through the inside of the valve on its way to the upper cylinder. In order to afford adequate cushioning for a valve so large and heavy as this one, the designer provided a special cylinder for the purpose, shown at the right of and below the high-pressure valve chest in the vertical section. The high-pressure eccentric, it will be noticed, is mounted on the outside of the crank case, next to the governor wheel, as in the regular Westinghouse compound engines, the motion being transmitted to the valve rod proper through several rocker arms and a connection with the cushioning cylinder plunger in the manner shown. The cushioning medium in this cylinder may be either air or steam, and when steam connections are made to the cylinder, it may be used as a starting cylinder for the high-pressure valve, connection of the latter with its eccentric being temporarily broken by a special disengaging gear provided for the purpose.

The low-pressure eccentric which, unlike the automatically governed high-pressure one, provides for a fixed cut-off, is mounted inside of the crank case and connects with a cross head from which two rods lead off to the low-pressure valve, straddling that on the high-pressure cylinder. The engines are all direct-connected to Westinghouse electric generators, and run at a speed of 200 revolutions per minute. The high and low-pressure cylinders measure respectively twenty-two and one-half and thirty-seven inches in diameter, and have a stroke of twenty-two inches.

FROM MINE TO FURNACE.

By John Birkinbine, Past Pres. Am. Inst. M. E.

Third Paper.



IN order to produce iron ore at low cost, it is essential that the management should employ labor-saving devices and introduce economic methods. For this purpose, in a number of cases, several large mines are operated under one management, thus reducing the fixed charges per ton of product. By far the larger proportion of iron ore mined in the United States is obtained from a comparatively few of the more important mines. In the year 1892, for example, 10,883,677 gross tons, or 66.78 per cent. of the total output, came from fifty-nine mines, each of which contributed 50,000 gross tons or over.

In 1892 there was one mining company which produced over 1,000,000 gross tons of ore ; four companies, which produced over 500,000 tons each (and of these three exceeded 600,000 tons); two produced over 400,000 tons ; five, between 300,000 and 400,000 tons ; four, between 200,000 and 300,000 ; twenty-two, between 100,000 and 200,000 tons, and thirty-three, between 50,000 and 100,000 tons, making a total of seventy-nine mines each producing 50,000 tons or over in 1892.

If now we estimate the labor required to mine the ore, load it on cars and transport it to its destination, we see the importance of this industry which employs over 50,000 men. But the mechanical appliances used are also features of interest, and the hoisting engines, pumps, air compressors, rock drills, washers and jigs connected with the mines have greatly influenced the advance in mechanical skill of operation.

METHODS OF MINING.

The successful pioneer iron enterprise in this country was in Massachusetts in the year 1645; much of that used being bog or pond ore, and one plant in Canada is still operated chiefly on this class of brown hematite ore. The following illustrates the way in which pond ores were obtained in Massachusetts in the year 1794 : † "Vast quantities of iron, both cast and wrought, have been made in this part of the country for more than a hundred years past ; but it was chiefly out of bog ore, until that kind was much exhausted in these parts. About the year 1747 it was discovered that there was an iron mine in the bottom of our great pond at Assowamset ; and after some years it became the main ore that was used in the town, both at furnaces and forges, and much of it has been carried into the neighboring places for the same purpose. Men go out with boats, and make use of instruments much like those with which oysters are taken, to get up the ore from the bottom of the pond. I am told that for a number of years a man would take up and bring to shore two tons of it in a day, but now it is so much exhausted that half a ton is reckoned a good day's work for one man. But in an adjacent pond it is now plentiful

† Vide Volume of Manufacturers ; Tenth Census, page 798.

where the water is twenty feet deep, and much is taken from that depth, as well as from shoaler water. It has also been plenty in a pond in the town of Carver, where they have a furnace upon the stream which runs from it. The quantity of this treasure, which hath been taken out of the bottom of clear ponds, is said to have been sometimes as much as 500 tons in a year." The average price of these pond ores was about $6 per ton, delivered at the furnace.

Nearly all of the iron ore mined in the earlier history of the iron industry was of the bog or pond varieties, and it was not until the commencement of the eighteenth century that any of the magnetic ores of New Jersey were utilized. The Dickerson Mine, which lately closed down, was one of the first mines of this character of ore opened, being located in 1716. The ore was often carried to the iron works in leather bags on pack horses.

Blast furnaces increasing in number and size required larger supplies of iron ore, flux and fuel, and to meet this it was necessary to employ other methods than those of dragging for ore. At first most of the mines were worked "open cut," but as the demands increased it became necessary to work underground so as to avoid heavy stripping, and danger from slides. There are, however, numerous open cut mines wrought at present and some large underground operations are being transformed into open cuts. The pick and the shovel, while still used, are largely supplemented by the steam, air or electric drills, and in some cases by steam shovels. High explosives have displaced much of the ordinary powder, and the wagons or carts drawn to the surface by horses or mules are to a great extent superseded by hoisting appliances operated by steam-power or by compressed air, and in place of ore carried in wagons or on pack saddles, we have the rapid and cheap transportation by steam railroads to supplement that shipped by water. The specular ores, which were first mined in Michigan in 1847, owing to low water transportation rates and the high percentage of iron they contain, came rapidly into favor, and it may be of interest to draw a comparison between the pond ore exploitation described above and one of the modern iron ore mines of the Lake Superior district.

At the Chapin Mine at Iron Mountain, Mich., the ore is taken from four shafts, ranging from 300 to over 800 feet in depth, and from an open pit of over an acre in area. The fourth shaft was sunk through a stratum of quicksand, and in order to pass this, a circle of iron pipes was driven and connected with a refrigerating machine. This reduced the temperature of the contents of the pipe to about zero, freezing the quicksand, and, keeping it frozen, this was then drilled and blasted like rock. The machinery of the mine is run chiefly by means of compressed air, although there is ample boiler capacity to operate the entire plant in case of accident to the compressor plant. This compressed air is carried a distance of three miles in wrought-iron pipe twenty-four inches in diameter. The Quinnesec Falls furnish, under a head of about fifty-two feet, the water to three forty-eight inch and one fifty-four inch turbine. There are three pairs of thirty-two inch diameter and sixty inch stroke, and one pair of thirty-six inch diameter and sixty inch stroke compressors. This compressed air is the motive power for the hoisting plant and also for more than 100 power drills. The number of employees varies from 1800 to nearly 2000. The ore is found in four large lenses, and is broken down by means of power drills and high explosives, loaded on mine cars, taken to the shafts, hoisted to the surface, where a cable conveys it to the trestle, on which the cars are automatically dumped into railroad cars or taken to the stock pile, from which the ore is afterward loaded on railroad cars by means of a steam shovel. By this means a twenty-ton car has been loaded in four minutes. As much as 2700 tons of ore have been hoisted from one shaft in twenty-four hours, and in one year over 700,000 tons were mined.

Generally speaking, most of the brown hematite iron ores are won either from open cut or open pit workings, while the red hematites and magnetites are usually obtained from underground operations. The carbonate ores also are mostly worked underground. There are numerous exceptions to the rule, but, taken as a whole, the above statement will be found to be approximately correct.

In order to obtain some idea as to the depth to which the workings were carried, inquiries were made as to the maximum depth obtained both vertically by modern power drills and illuminated by electric light.

The vertical and slope distances given refer to different operations, and in many cases the slopes enter the sides of steep hills, so that no vertical depth is recorded.

There are eight mines reporting a vertical depth of 1000 feet or over, and of these seven are located in Michigan.

While it would be interesting to follow the details of some of the special features of the great producers, it is not practicable in the limited space to do more than call attention to some typical illustrations

Depths of Mine Workings in Various States in 1892.

States.	Vertically.	On Slope.
Alabama	Surface workings to 200 feet	Surface workings to 1100 feet.
Colorado	15 feet to 650 feet	None given.
Connecticut	100 feet to 140 feet	"
Georgia	Surface workings to 200 feet	100 feet to 400 feet.
Kentucky	Surface workings to 150 feet	None given.
Maryland	Surface workings to 80 feet	Surface workings to 350 feet.
Massachusetts	165 feet to 260 feet	285 feet to 320 feet.
Michigan	75 feet to 1460 feet	90 feet to 1500 feet.
Minnesota	Surface workings to 490 feet	None given.
Missouri	60 feet to 205 feet	150 feet to 480 feet.
Montana	30 feet to 100 feet	140 feet to 200 feet.
New Jersey	80 feet to 1200 feet	130 feet to 4350 feet.
New York	18 feet to 985 feet	130 feet to 2575 feet.
North Carolina	100 feet to 200 feet	100 feet.
Ohio	Surface workings to 80 feet	15 feet to 860 feet.
Pennsylvania	Surface workings to 390 feet	Surface workings to 1080 feet.
Tennessee	Surface workings to 250 feet	150 feet to 500 feet.
Texas	Surface workings to 70 feet	Surface workings to 100 feet.
Virginia	Surface workings to 430 feet	Surface workings to 600 feet.
Wisconsin	50 feet to 630 feet	330 feet to 940 feet.
Other States	80 feet to 300 feet	89 feet to 300 feet.

and on the slope at the different mines, and from the answers received the above table, showing the minimum and maximum depths in each State, has been prepared. Unless the details of every mine were investigated no average depth of mine could be given, nor is such essential, the table presenting an idea of the extent to which exploitations are at present carried for mining iron ore. Most of the shafts and slopes are equipped with excellent machinery for handling the ore and raising water, and the great areas of underground workings are in many cases carried on of mines of different character, or the means employed for their exploitation, and the instances have been selected more with the object of exhibiting prominent features, than as an attempt to cover various details of operation. They are offered to illustrate the peculiarities of mining the different characters of iron ore in various sections of the country.

During the present year considerable interest has been attracted to the apparently large deposits of iron ore of a satisfactory character, which can be easily mined from what is known as the

Mesabi range, in Minnesota, and this locality is now passing through the developing stages, which have characterized the earlier history of other sections in the Lake Superior regions which have become producers of iron ore.

The pioneers penetrate the forest, generally "packing" their provisions and tools with them, erect a log cabin, and start the preliminary operations with pick, shovel and hand drill, supplemented by hand winch, bucket and pump. If an apparently satisfactory deposit is found, machinery soon takes the place of manual labor, and compressed air is early applied to these enterprises. The necessity of labor saving appliances demands the prompt application of such economies, and not only are power drills introduced in the early history of most of the mines, but diamond drills are among the implements which may be found at work in the heart of a forest or in the midst of swamps seeking to discover the subterranean secrets. In fact, one who has never visited a newly developing iron region, would be surprised to note how quickly the economies for exploring or exploiting mines, and for transporting the material from them are introduced.

Interesting lessons can be learned by visits to mines in different sections of the country, which are operated to produce the various classes of iron ores. The red hematite mines of the Minnesota Iron Company in Minnesota, the Norrie mine, the Ashland, the Colby, of the Gogebic range; the Lake Superior, the Cleveland, the Champion, in the Marquette range, the Ludington, the Florence, the Chapin and the Penn Iron Mining Company, in the Menominee range, each possess some quality of interest to the investigator, either by the depth to which the deposit is wrought, sometimes over 1400 feet; the extent of the underground drifts, the occurrence of ore in the lenses, and in some cases the admixture of magnetite and hematite, all offering in-

"HYDRAULICKING" IRON ORE AT IRON MOUNTAIN, MO.

teresting themes for study. The Nevada system of timbering, which is liberally employed in the Lake Superior mines, is also in strong contrast with the solid ore columns, 300 feet high, supporting the roof at the magnetite mines at Port Henry, N. Y., and similar though shorter columns at Lyon Mountain, N. Y., and other magnetic mines.

More contrasts are found in the open cut and underground work in different localities; the Tilly Foster mine of magnetite in New York State has become renowned for the efforts there made to secure its dangerous walls, commencing with great arches of brick, sustaining massive braces of concrete, which were placed in rooms which had been worked out, so as to permit removal of pillars, and ending with the blasting away of 500,000 tons of hanging wall rock, so as to make the work an open cut. On the other hand, the Iron Mountain, Mo., originally wrought as an open cut, is principally exploited by underground workings to remove a mass of detrital ore from the original deposits which had been subsequently covered by rock of later deposition. The Cornwall ore hills have been wrought open cut until over 12,000,000 tons have been removed from them, an amount nearly four times as great as that won from Iron Mountain, Mo., and there are to-day magnificent faces of this soft magnetite exposed in the hills and railroad cuts passing through the Cornwall property. The mining of the carbonate ore deposits near the Hudson River, N. Y., the winning of the fossil ores in Northern New York, the stripping of sand from the bog deposits of Texas, the handling of the brown hematites of Alabama, Tennessee and other States by steam shovels, all add to the variety of methods and appliances used.

Considerable interest has for several years been exhibited in the concentration of magnetic iron ores by means of magnetic separators. This is not a novelty, for the United States Patent Office has issued nearly 150 patents (some of them half a century old) for various forms of magnetic separators. The revival of interest in the concentration of lean magnetic iron ores is fortunately at a time when improvements in machinery for reducing in size and handling large quantities of material are supplemented by advanced knowledge of electromagnetic appliances. The extent to which the process can be applied commercially to many ores, can be decided only after a thorough investigation, embracing the chemical and physical characteristics of the ore, the quantity accessible, the facilities for obtaining it, and the available market for concentrated ore.

This method of beneficiating iron ores is confined to magnetite, or possibly to some ores which can by roasting or other process be made sufficiently magnetic to permit of their concentration by the appliances mentioned. Most of the work done has been in enriching lean magnetite, although some ores carrying high percentages of iron have been fed to magnetic separators for the purpose of reducing the amount of phosphorus and sulphur. The predominance of magnetic iron ore in New York and New Jersey, and the existence of large deposits of this class of ore in Pennsylvania and North Carolina, have naturally attracted to these States most of the development in concentrating plants.

There is no question but what the amounts of sulphur, phosphorus, silica, and in some cases titanium, existing in magnetites can generally be considerably reduced if the material is sized and passed through magnetic separators; the degree of perfection reached being influenced by such reduction in size as will actually permit the mechanical separation of the pure magnetite from the other ingredients. In some of the titaniferous iron ores, this element is so combined as to be magnetic, and similarly the sulphur in other ores is in such combination as to make it partially magnetic. It may be possible with improved machinery and greater knowledge to separate various materials from each other, which differ but

slightly in magnetism, but present practice is confined to separating magnetic from non-magnetic material, and the results achieved depend largely upon the comminution of the material, the rapidity with which it is fed on the separator and the perfection of the machine.

We may consider the term "concentrates" as applied only to ore which has been comminuted by means of crushing machinery and then passed through water-jigs or magnetic separators to remove materials which lower the grade of the ore.

In jigging, the crushed ore is agitated, water being introduced, which removes the lighter material, while the heavier iron ore sinks and is conveyed from the jig as it is separated. It was in this way that at Lyon Mountain, N. Y., the Chateaugay Ore and Iron Company treats the lean magnetite taken from the mines, and a similar method was followed at Iron Mountain, Mo., for the separation of the leaner red hematites.

Although the forms of magnetic separators vary, they may be classed under three general heads:

(1) Altering the trajectory of falling material by introducing the attraction of a magnet, to draw the magnetic portion away from the non-magnetic.

(2) Feeding the ore to a revolving drum or drums, in which is a magnet core, the shells of the drum being either of alternate magnetic and non-magnetic strips, or entirely of magnetic or non-magnetic material. In some of these drums the magnet core is wound so as to exert a constant polarity, in others a series of magnets of alternate polarity compose the core, and in some opposite drums are of opposite polarity. When two drums are used, they are placed so as to revolve toward each other, the ore passing between them, or they are arranged tandem, the drums revolving in the same direction, but sometime at different speeds and with different degrees of magnetic force, so that the ore fed from one drum to the other receives successive treatment. Machines are also arranged with more than two drums.

(3) Belt machines in which the ore is fed to a belt or series of belts passing under or over magnets or magnetic drums, the machines working sometimes in water and sometimes dry. In some of the machines the polarity is maintained continuously by means of pole pieces, in others the material is constantly submitted to magnets of alternate polarity, the belts being placed so as to run either vertically, horizontally, or on an incline, according as the conditions require.

These separators are used either at the mines to enrich the ore, at steel works and rolling mills to remove the magnetic particles from slag and dirt, to separate iron ore from pottery clay or from emery—and in one instance iron ore occurring as a hematite with zinc ore is treated in a roasting furnace after being comminuted, and becoming magnetic, can be thus separated.

During the year 1892 there were produced 9555 gross tons of hand-picked or cobbed ore, 163,444 gross tons of magnetically separated ore, and 93,627 gross tons of jigged ore.

So far as transportation of these large quantities of ore mined is concerned, it is interesting to note that all of the ore does not pass over railroads and much of it reaches the blast furnaces by both rail and water transportation. The majority of the ores from the Lake Superior region are carried by rail to shipping ports, thence by vessel to the lower lake ports and there re-handled into cars which travel over the railroads to the blast furnaces. Several blast furnace plants are located so as to unload foreign ores at their docks, but most of the foreign ore is transported from the ports where received by railroad cars or by lighters to the points of consumption. A number of iron works also rely largely on the local deposits, from which the ore is carried by wagons or carts, or by wire rope transmission, or by tramroad to the furnaces. The proportion, however, of ore which is not hauled over the railroads is quite small, and an illustration of the volume of business based upon the tonnage is a proper one. Generally speaking, an

REMOVING THE HANGING WALL AT THE TILLY FOSTER MINE, N. Y.

average load of fifteen net tons may be allowed per car, which is more probably above than below the actual average, so that the amount of ore consumed in the year 1892, viz: 16,296,666 long tons or 18,252,266 net tons, would require 1,216,818 cars to carry it, or say 40,560 trains of thirty cars each; five such trains, with motive power and caboose would occupy one mile of track when standing close together, or the year's product would occupy 8112 miles of track, a distance equal to nearly three times that from New York to San Francisco. If all this traffic passed a given point there would be 111 trains per day, or a train every thirteen minutes during the year.

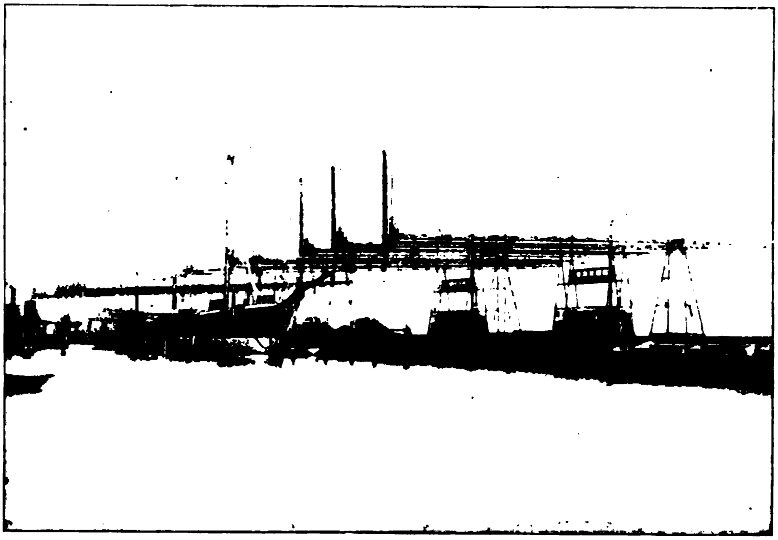
A similar calculation would show that the number of corresponding trains required to carry the 141,000,000 tons of coal mined in 1892 would be nearly nine times as great as would be necessary to transport the iron ore, and the trackage occupied would be correspondingly greater.

Much of the iron ore from Lake Superior region, from New York, and some from other States, also large quantities of coal, have to be transported long distances to reach points of consumption, and reshipment is necessary where the transportations are made by both rail and water. An essential of such rehandling and transporting is that it should be done in the least possible time and at small expense, in order to enable the ores to compete with others, which, although not so rich, are found nearer the blast furnaces. As the principal cost of rehandling is for labor, large amounts of money have been expended by different iron and railroad companies for docks and cars built specially for the purpose, so as to bring this item to the lowest point practicable, and also make it possible to handle greater quantities of

material than by manual labor. It is now no unusual thing for ore to be taken from the mine in "skips," automatically dumped into specially constructed railroad cars or into ore bins from which it can be discharged into cars, then hauled in these cars to ore docks, where the drop bottoms of the cars are opened and the ore falls into pockets, from which it is run into the hold of the vessel, and in this whole process the only labor necessary is to open the doors of the bins or the bottoms of the railroad cars.

The ore shipping docks on Lakes Superior and Michigan (the largest in the country, if not in the world), in connection with the ore receiving docks at the lower lake ports (fitted with bridge tramway plants), the railroad cars, and in some cases vessels specially constructed for this purpose, have aided materially in reducing the cost of transporting iron ore to points of consumption. The furnace manager, by means of advanced methods, cheaper or richer iron ores, improved facilities, and larger output, has lessened the cost of pig iron, which in turn has lowered the price of manufactured iron and steel, which has been one of the most important, if not the most important factor in bringing this country up to its present degree of prosperity.

In addition to the seventeen shipping docks erected to handle iron ores from the Lake Superior region, there are others of less magnitude on Lake Champlain, on the Mississippi River, and elsewhere, but the proportions of the docks on Lakes Superior and Michigan and the quantities of ore handled by them are much greater than the others. The same holds true concerning the ore-receiving docks at lower lake ports, for from this region was obtained fifty-eight per cent. of all the iron ore mined in the United States in 1892.



AN IRON ORE RECEIVING DOCK.

The ore shipping docks consist of a wooden structure, built on piles. The top of the dock is from thirty-eight feet to fifty-two feet above the ordinary water level, and wide enough to accommodate from two to five lines of railroad tracks. The ore docks have from fifty to 300 pockets, holding from eighty to 170 tons of ore each. The pockets are sheathed with plate iron and slope downward toward the water

side of the dock. At the bottom of each pocket is a door which is controlled from the top of the dock. When it is desired to load a vessel, plate-iron chutes, usually semi-circular in form, are lowered into the hatches of the boat, the doors which connect these chutes to the respective pocket are raised, and the ore discharges itself into the hold of the vessel.

Marquette, Mich., is the port from which the first Lake Superior iron ore was sent, and up to the close of the year 1892 there have been loaded into vessels 18,651,580 tons at this port, which in 1892 ranked fourth, with a shipment of 1,034,700 gross tons, all from the Marquette range.

In 1865, Escanaba, Mich., claimed a share of the shipments from the Marquette range, this port and Marquette keeping company until 1879, when Escanaba took a liberal lead, chiefly by reason of the development of the Menominee range, commencing in 1877, and this lead has been continually maintained. In 1892, 4,012,197 gross tons, or nearly one-half of the lake shipments, were sent from this port. Of this the Marquette range contributed 1,392,148 gross tons, the Menominee range 2,107,506 tons, and the Gogebic range the balance, 512,543 gross tons. Since 1865 there has been handled at the Escanaba docks a total of 33,975,454 tons.

The following will indicate how rapidly ore is handled by these docks: One steamer was loaded with 1659 long tons of iron ore in forty-five minutes; others with 3027 gross tons in three hours, 3132 gross tons in four hours, 2379 gross tons in two hours, 1927 gross tons in two hours, 2502 gross tons in two hours, 1850 gross tons in forty-five minutes. In this last case just one hour elapsed between the arrival of the boat at the dock and its departure. The record for most rapid loading is that of 980 tons, which were run into a steamer in four and three-quarter minutes. The maximum quantity handled at the Escanaba docks into vessels in twenty-four hours was 42,320 gross tons.

The nearly simultaneous development of the Gogebic iron range in Michigan and Wisconsin and the Vermilion iron range in Minnesota caused the erection of shipping docks, three for the former at Ashland, Wis., and two for the latter at Two Harbors, Minn., both ports making their first shipment in 1884. Ashland, however, soon outstripped its rival and in 1892 ranked second as a shipping port, with 2,221,241 gross tons as its output. Since the docks were erected at Ashland in 1884, 9,981,266 tons of ore have been shipped.

In 1892 Two Harbors, Minn., ranked third, 1,155,498 gross tons being shipped, and the total from 1884 to the close of 1892 was 5,186,397 gross tons. Receiving docks are also about completed at Duluth, Minn., to accommodate the anticipated increased shipments from the Mesabi Minnesota mines.

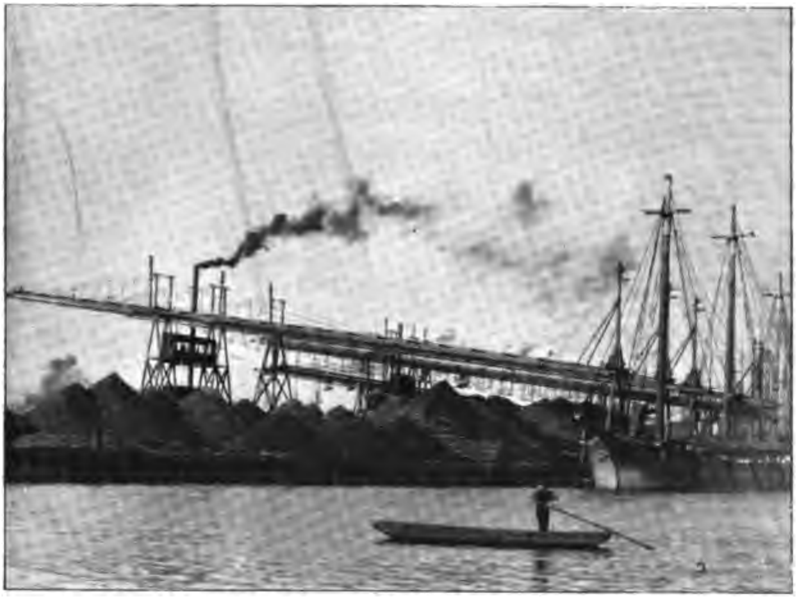
Gladstone, Mich., made its first shipment of ore in 1889, and serves as an additional and competing shipping point for the mines of the Menominee range. In 1892, 115,907 gross tons were shipped.

The year 1892 also chronicled a new shipping port for the Mesabi ores, viz., Superior, Wisconsin, from which in that year 4245 gross tons were sent forward, but largely increased shipments are expected in 1893.

The length of the seventeen ore shipping docks, independent of approaches, varies from 400 feet to 1800 feet. The aggregate of all being 19,342 feet, or say three and two-thirds miles. They contain 3189 pockets, have a total capacity of 385,350 long tons, and cost, approximately, $4,500,000.

In connection with these docks in 1891 the railroad companies owned a total ot 12,526 cars, built for use in transporting iron ore, with an aggregate capacity of 187,550 tons of iron ore, their total cost being estimated at $3,600,000.

Six mining companies on Lake Superior owned in 1891 a total of thirty-three vessels, mostly steamships, with an aggregate tonnage of 80,750, especially devoted to the transportation



BRIDGE TRAMWAY ORE DOCK PLANT, BUILT BY THE BROWN HOISTING AND CONVEYING MACHINE CO., CLEVELAND, O.

of iron ore, and maintained by the iron ore producers.

The bulk of the lake shipments ot iron ore are taken to the lower lake ports—Cleveland, Fairport, Ashtabula, Toledo, Sandusky. Huron, Conneaut and Lorain, O.; Erie, Pa., and Buffalo, N. Y., for distribution to the various blast furnaces in Pennsylvania, Ohio, West Virginia, New York, etc. The remaining portion going direct to furnaces situated near to or on the great lakes, such as Milwaukee, Wis.; Chicago, Ill.; Detroit, Mich.; Tonawanda, N. Y., and to individual furnaces at various points in Michigan and Wisconsin. Most of the furnaces on the lakes or their estuaries have special appliances for handling iron ore, but it is at the first-mentioned ports on Lake Erie that the larger receiving docks are located, Cleveland having four, Buffalo three, Ashtabula and Fairport two each, and the remaining ports one each.

Two of the receiving docks at Cleveland are each half a mile in length and have a storage width of 350 feet; one at Fairport has a water front of one mile and a width for storage purpose of from 180 to 350 feet. As the ore is stored in piles from twenty-five to fifty feet in height, the capacity of each of these docks is from 1,000,000 to 1,500,000 long tons, and the average storage capacity of the receiving docks is 300 to 500 tons per foot of water front. During the shipping season, from May to October, the ore is brought to these ports, unloaded, a portion being handled directly to railroad cars, and the balance stocked, being shipped to the blast furnaces during the winter months. The largest stock on hand at lake ports in the past nine years was on December 1, 1892, when 4,149,451 gross tons were on the docks. The largest stock of ore at the opening of navigation was that on May 1, 1891, when the heavy stocks of the previous year had been reduced to 2,662,223 tons.

THE GLASGOW AND WEST OF SCOTLAND TECHNICAL COLLEGE.

By T. Crichton Fulton.

THE Glasgow and West of Scotland Technical College was founded in its present form by an Order of the Queen in Council, dated November 26th, 1886, according to a scheme framed by the commissioners appointed under the provisions of the "Educational Endowments (Scotland) Act" of 1882, whereby Anderson's College and the College of Science and Arts, together with some less important bodies, were placed under the control of one governing body. Though the present account is meant to deal principally with the electrical engineering department of the work, still a brief historical notice of the two chief institutions above mentioned may not be out of place, more especially as it will include whatever of ancient history belongs to this comparatively recent subject of technical education. The above remark is literally true of Great Britain, whatever relation it may have to the birth and growth of such education in Europe or in America.

Perhaps in no corner of the civilized world was the stupendous work which James Watt accomplished in the latter half of the last century so immediately or so strikingly felt as in his own corner of Blydesdale. Factories and engineering works, great and small, sprang into being, bringing in their train a small army of artisans and mechanics. From these soon arose the cry for more light on the natural laws and principles on which depended the various operations of their daily life. The hour had come and it found the man, for in 1795 John Anderson, M. A., F. R. S., professor of natural philosophy in the University of Glasgow, bequeathed the bulk of his property, including his library, museum, and some valuable philosophical apparatus "to the public for the good of mankind and the improvement of science, in an institution to be denominated 'Anderson's University,' and to be managed by eighty-one trustees." In 1796, the institution was duly incorporated by a seal of cause, or charter, from the magistrates of Glasgow, with Dr. Thomas Garnett as its first professor of natural philosophy. His duties at first consisted of delivering a daily course of lectures on natural philosophy, and two popular evening courses on that subject and on chemistry. In 1799, the Royal Institution of London was founded on lines similar to those of Anderson's University, and for a similar purpose, and thither went Dr. Garnett as its first professor. He was succeeded in Glasgow by Dr. George Birkbeck, who, in addition to his other duties, instituted courses of popular free lectures on mechanics and allied subjects. From these lectures sprang the mechanics' institutions—for many years a prominent feature in the workmen's life in every town of any size in Great Britain—the first of which was founded in Glasgow. Dr. Birkbeck went to London in 1804 and was succeeded by Dr. Andrew Ure, who retained the office for twenty-five years before he also was wanted in the metropolis. After him came Dr. Thomas Graham, the eminent chemist, who was subsequently ap-

pointed master of the mint. The present occupant of the chair of natural philosophy is Professor James Blyth, F. R. S. E., whose immediate forerunner was Professor George Forbes, F. R. S., so well known in America as an electrical engineer, and he again was preceded by Professor Herschel, a nephew (I think) of the famous Sir John Herschel. At various times this university has been the recipient of valuable gifts and bequests, notably the "Freeland Mortification" of £12,500 for the periodical delivery of popular lectures on chemistry, on mechanical and experimental physics and on anatomy and physiology; and the "Young" chair of technical chemistry, for the founding and endowing of which the late James Young—the inventor of the method of distilling paraffine from shale—settled in trust a sum of £10,500.

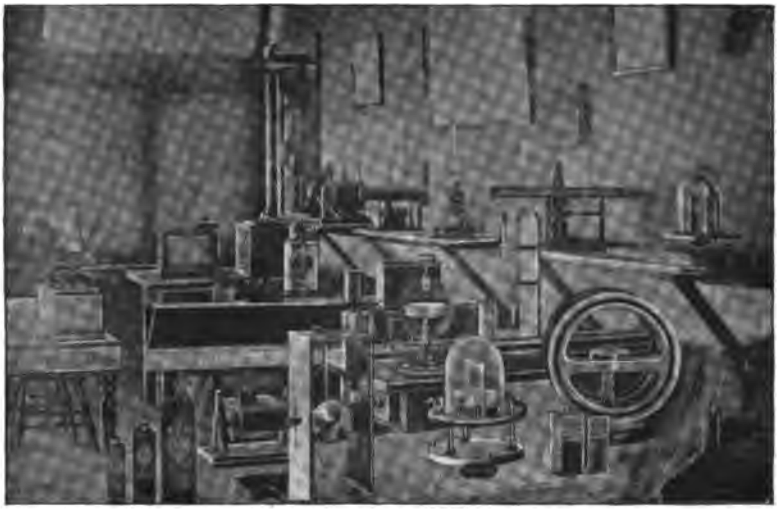
The College of Science and Arts was originally known and did good work as the Mechanics' Institution. It was founded under the latter name in 1823 by a number of students who had been attending the classes in mechanics at Anderson's University, and it had for its first president the man to whom must be given the credit of its conception,—the renowned Dr. Birkbeck. The classes at first met in a hall in North Albion street, where evening lectures were delivered on mechanics, chemistry, mathematics, natural philosophy, and several other subjects. These lectures were attended by about 800 students. In 1831, larger premises were opened in North Hanover street, and in 1862 the classes were removed to a handsome building at No. 38 Bath street, day classes being established at the same time. Strange to say, the fortunes of the institution soon after this date steadily declined until 1879, when a thorough re-organization of the whole concern took place, and its name was changed to "College of Science and Arts." In the following year Mr. Andrew Jamieson was appointed principal, and thenceforward the work was presented with renewed vigor and unexampled success. Principal Jamieson found the popularity of the institution at a very low ebb, there being only between 200 and 300 students in attendance, while the annual Government grant amounted to little over £100. Soon, however, his energy, capacity for administration and organization, and especially his enthusiasm, made themselves felt, and the classes increased both in size and numbers by leaps and bounds, until, in 1887, when the College of Science and Arts was incorporated with the Glasgow and West of Scotland Technical College, the number of students attending the various classes had increased to about 1200; the number of enrollments to 2150; and the annual grant to considerably more than £2000.

The management of the Glasgow and West of Scotland Technical College is vested in a body of thirty-one governors, some of whom are elected for life and the rest annually, by the town council of Glasgow, by such educational institutions as the Glasgow University, the school board, and the city educational endowments board, by incorporations of traders, procurators and the like, and by the trustees of the various institutions forming the college. These governors have appointed committees of their number to superintend matters of detail relating to finance, property, teaching and staff, bursaries, and libraries and museum. A wise arrangement is that by which the professors co-operate with the members of the teaching and staff committee in the discussion of all matters relating to the teaching and examination arrangements.

From the comparatively humble beginning which has been briefly indicated, the college has risen to much greater dimensions, and is, as indeed it ought to be, a power for good throughout the west of Scotland. It possesses a staff of nine professors and seventeen lecturers, besides a large and efficient body of assistants. The professorial chairs are as follows: Natural philosophy, chemistry, engineering (including electrical engineering), mechanical engineering, technical chemistry, mathematics, applied mechanics,

metallurgy, and agriculture. Besides these, the subjects treated of by the lecturers include, among others, agricultural chemistry, geology, plumbing, building construction, naval architecture, mining, and civil engineering. In all, the scope of the college work embraces no fewer than thirty-five distinct subjects.

The day classes are conducted generally between the hours of 9 and 4, though some classes meet as late as 4 and even 5 o'clock. The evening lectures and laboratory work are carried on between the hours of 7 and 10. The sessions extend from the first week in October till the last week in April, with a break of about three weeks at Christmas and the New Year. For day students, the fees vary from one to ten guineas per class for the session, but in some of the lecture classes and in all the laboratory classes there is a monthly fee for students who are unable to attend during the entire session. The day classes are carried on without reference to the examinational requirements of any outside body, and are, as far as possible, self-supporting. The evening classes, on the other hand, are conducted in most cases on the lines of instruction laid down in the syllabuses of the science and art department and of the city and guilds of London Institute, with the view of passing the examinations set by those bodies and of earning their pecuniary grants. The chief exceptions to this rule are in the case of the honors classes and laboratory practice. The fees for evening students are as low as half-a-crown for some subjects, and as high as forty and even fifty shillings for others. In the great majority of the classes, however, a conditional fee only is charged at the commencement of the session, which averages about six or seven shillings for lectures and about twenty-five shillings for laboratory work. This fee is all that students have to pay provided they carry out the obligations which they are required to sign when they matriculate, viz.,—that they will attend regularly, do the home exercises faithfully, and present themselves at the class and May examinations. Should any student fail in these respects, he is called upon to pay the full fee. The most of the classes meet for lectures on one evening in the week ; but in some of them, such as those of mathematics, mechanics, machine design and drawing,



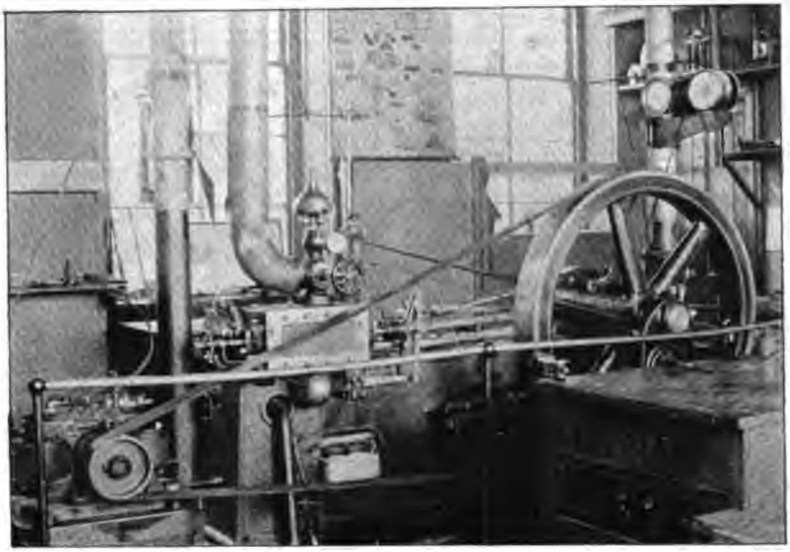
A VIEW OF THE ELECTRICAL LABORATORY.

and generally in the laboratory classes, work is conducted on two evenings a week.

The college grants diplomas in the following departments of applied science: (1) civil engineering; (2) mechanical engineering; (3) naval architecture; (4) electrical engineering; (5) architecture; (6) chemical engineering; (7) metallurgy; (8) mining engineering; (9) agriculture, and in general science, for the special behoof of teachers and others; (10) mathematics and physics; (11) chemistry. The ordinary courses for these, as arranged and recommended by the governors, extend over three years, but students may spread the classes over a longer term of years, or vary their order as they see fit. The diplomas are accepted by the universities of Edinburgh and Glasgow as an equivalent of two sessions' work and attendance for the degree of Bachelor of Science. The certificates of the college are granted to evening students, and are divided into junior and senior certificates. They are granted in all the subjects above mentioned, and, in addition, in building construction, chemical industries, textile industries, art industries, and commerce. Courses of study for these certificates, extending over three evening sessions, have also been arranged and are recommended, but are not compulsory.

That the college supplies a decided want and is adequately appreciated is amply evident from the number of students enrolled. This number has been steadily increasing year by year until some of the workshops, laboratories and class-rooms are inconveniently crowded. Every session sees additions made to the accommodation, and at every session the cry goes up for more room. Quite recently, the greater part of an adjoining building was added to the accommodation of the classes attending the science and arts buildings, while during the past summer the whole of the premises immediately west of the Andersonian building have been annexed and fitted up as laboratories and lecture rooms. As at present arranged, the Andersonian buildings are devoted to natural philosophy, chemistry and mathematics, while in the science and arts buildings no classes now meet, save those of engineering proper and the allied subjects of naval architecture, building construction, and drawing. The total number of day students on the roll last session was 220, while the evening students numbered no fewer than 2644. The enrollments, however, far exceeded these numbers, being respectively 659 and 3663. In those classes which are of special interest to readers of this magazine—those under the charge of Professor Jamieson and his assistants—the numbers were for evening students as follows: Applied mechanics, 214; steam and steam engines, 210; magnetism and electricity, 195; electrical engineering, 159; or a total of 770. The numbers of day students were: Metal workshop, 42; wood workshop, 28; electrical laboratory, 22; or 92 in all.

Andrew Jamieson, professor of engineering in the college, who conducts all the classes named above, is a son of the Reverend George Jamieson, D. D., of the Cathedral, Old Aberdeen, and was born in 1849. His education was received at the Gymnasium, Old Aberdeen, and Aberdeen University. He served a complete apprenticeship to engineering at the Aberdeen Iron Works, under Mr. Thomas Russell, of Hall, Russell & Co., shipbuilders and engineers, and was afterward employed by the Great North of Scotland Railway as draughtsman. In 1873, he was appointed assistant to Sir William Thomson, and the late Professor Fleeming Jenkin, in connection with the manufacture of the Western, the Brazilian, and other submarine cables. In 1874 Mr. Jamieson accompanied the cable expedition to South America, where he remained as chief assistant electrician till July, 1876, when he returned to Scotland. He was next sent out by the Eastern Telegraph Company as electrician in charge of their Mediterranean station, and from the beginning of 1877 till 1880 he took a prominent part



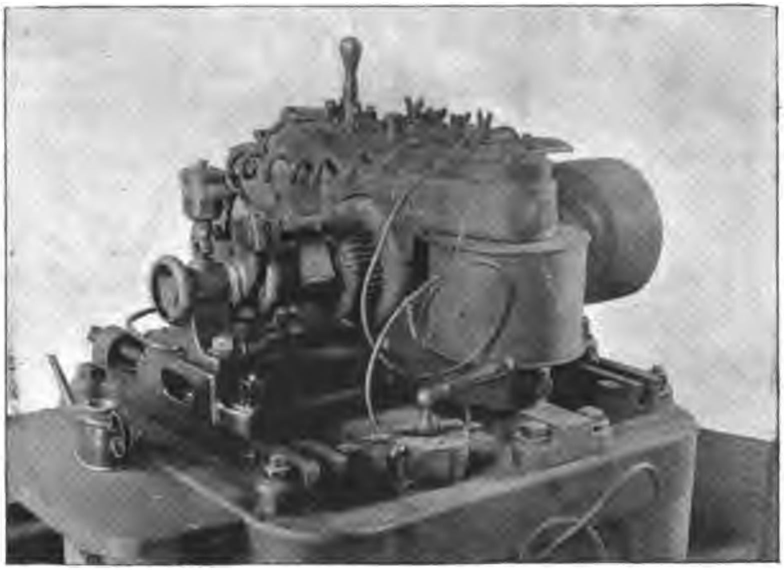
EXPERIMENTAL STEAM ENGINE IN THE TESTING LABORATORY.

in all the important cable expeditions of that company. Among his other duties was that of lecturing on magnetism and electricity, and on submarine telegraphy to the various staffs at the stations under his control.

In July, 1880, Mr. Jamieson was appointed principal of the College of Science and Arts where, as has already been indicated, his labors were rewarded by great success. In 1887, on the formation of the Glasgow and West of Scotland Technical College, he received his present title. Professor Jamieson is a fellow of the Royal Society of Edinburgh, a member of the Institution of Civil Engineers, and of the Institution of Electrical Engineers of Great Britain, and a member of the Council of the Institution of Engineers and Shipbuilders in Scotland, and also of the Glasgow Philosophical Institution. He is eminently a busy man and never seems happier than when he is head over ears immersed in work. Besides his classes at the college he finds time to engage in various important works as consulting engineer; in fact, he was associated as consulting electrician with the first steamship on the Clyde which was lighted by incandescent lamps—the Cunarder Servia. As an author, Professor Jamieson has distinctly made his mark. Besides contributing a large number of papers to the transactions of the various scientific societies with which he is connected, which have brought him both honors and rewards, he is the joint author of a "Pocket-Book of Electrical Rules and Tables," which has gone through eight editions, and author of a Text-Book on Steam and Steam Engines, now in its seventh edition, elementary manuals of Steam and the Steam Engine, Magnetism and Electricity, and Applied Mechanics, and other works.

The workshops, over which Professor Jamieson rules with a kindly but despotic sway, are airy and well lighted apartments in the Science and Art Buildings, and are well stocked with the requisites of a good practical training in the use of tools. The metal shop contains five lathes; a vertical drilling machine, with both hand and automatic feed; vises; an experimental steam engine, and experimental dynamos. The "Thomas Russell Memorial Steam Engine" was presented to the college by Mrs. Russell, who adopted this sensible and useful method of commemorating her husband, with whom the pro-

fessor served his apprenticeship to engineering. It was designed by Professor Jamieson specially for the work, and has proved very useful as an educative medium. It is fitted with reversing link motion, speed indicator and speed-counter gauges, indicator cocks and connections, steam jacket, and also with devices whereby thermometers can be inserted at various points to ascertain the different temperatures. It has an expansion valve behind the slide valve and hand wheel, whereby the cut-off may be varied at will. It can be worked either non-condensing or with various forms of condensers, and adequate arrangements are made for finding all weights and temperatures of steam, hotwell and condensing water. The chief experimental dynamo is of the Mather and Platt "Manchester" type, and can be used as a simple series, shunt or as a compound wound machine, with both long and short shunt. It is supplied with all necessary volt and ampere meters, switches and resistance coils. The wood workshop is similarly well fitted up with all necessary benches, vises, etc., and also with three small wood-turning lathes. During the past year an additional workshop has been fitted up for the use of students of engineering, in the form of a blacksmith's shop. It is situated in the basement of the Science and Arts Buildings, and contains hearths, anvils, and all the other usual requisites of such a place.



AN EXPERIMENTAL DYNAMO.

Let us suppose now that a young electrical engineering student enters these workshops to learn to use his hands and head together. The methods adopted in training the young idea are as near as possible those of every-day workshop practice, these being the only ones which ultimately will be of service to him in earning his daily bread. The student has first of all to make a drawing either to scale or full size of the article which he is about to make. This approved of, he has to take out all the materials of the kind and quantity required. He then proceeds to make, to finish and, if necessary, to mount the article neatly ; and lastly he has to prove its correctness and efficiency by applying tests, as in the case of magnets, galvanometers and other apparatus. The branches taught in the

metal shop include electrical instrument making and repairing, and in the wood shop, pattern-making.

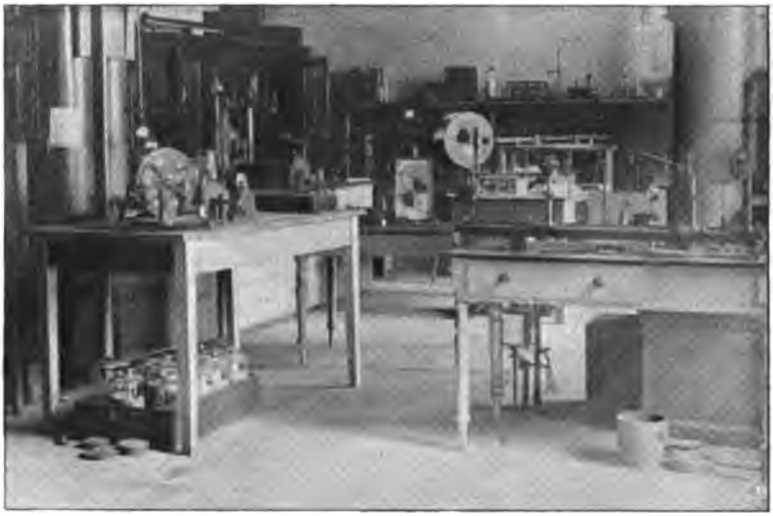
In the second year, the youthful electrician enters the electrical engineering laboratory, which is situated in the Science and Arts Buildings. This room contains ten separate testing tables, each one fitted with a securely fixed wall bench on which to rest a galvanometer, or other delicate instrument.

The laboratory is furnished with a large variety of apparatus of the best type and make, and a small room is specially fitted up for conducting magnetometric experiments, whilst a corner of the wood workshop has been set apart for the operation of joint-making.

Arrived at the laboratory, the student has first of all to sign the attendance register—this is done every day—and is then placed at a table along with two, or if the class is a very large one, three other students to go through the different steps of some experiment. He has first of all to sketch the various pieces of apparatus and examine them so as to understand the principle of their action. He then, along with the others, makes the necessary connections from a sketch supplied, and after verifying his connections, he is allowed to proceed. Having now gone through all the steps required, and verified his result, he is shifted with his companions from table to table until he has gone through a complete course of testing, measuring, and calculating, in connection with all the usual elementary experiments such as copper resistance by resistance box, metre bridge, equal deflections, and fall of potential methods, resistance of cells and galvanometers, specific resistance of metals, electromotive forces of different kinds of cells, measurement of current by tangent galvanometer, effect of heat on resistance, as well as some simple experiments in electrolysis. Nor is the practical side of his training at all neglected. He has to go through a complete and systematic course of jointing of wires and cables and has to mount these efforts of his 'prentice hand' on a neat varnished board. He is also allowed to assist the mechanical and advanced electrical engineering students in looking after the dynamos and steam engine, in taking indicator diagrams, in charging the storage cells and in various other ways. Throughout the session he has been noting and recording the results of the various experiments and submitting his note book as often as required to the laboratory instructor or to Professor Jamieson. He has also been attending (as indeed he was during the previous session) lectures in natural philosophy and mathematics and taking classes in geometrical drawing, and in machine and building construction and design. In the evenings also, he has been attending his professor's lectures in magnetism and electricity, and in electrical engineering in the large lecture hall of the Science and Arts Buildings.

Third-year students take up advanced work in the laboratory and are set to work at experiments with the magnetometer and quadrant electrometer, to find insulation resistance, test for faults, capacity of cables and to calibrate instruments. They are encouraged to undertake original work and to investigate new methods. They have the care of seeing that the dynamos, storage cells and lamps are maintained in good condition; and they share, along with the mechanical engineering students in the metal workshop, the duty of keeping the steam engine trim and tidy and fit for work. They are also associated with Professor Jamieson in whatever consulting work he may have on hand. In that capacity they have assisted, during the past session, in examining and testing various electric light installations in and around Glasgow; in testing, working out results and drawing up reports on gas and steam engines, primary battery cells, cables, dynamos, and electromotors; and in preparing drawings, plans, and specifications for new work. Such a training as this is in the highest degree practical, and is well fitted to lay a good solid foundation.

Instead of taking a workshop course,



A CORNER IN THE PHYSICAL LABORATORY.

or in lieu of one of the electrical laboratory courses, a student may choose to attend the physical laboratory. This room is situated in the Andersonian buildings and is under the care of Professor Blyth. It is extremely well provided with apparatus for performing all the usual experiments in mechanics, sound, light, heat, magnetism and electricity; and the student, beginning with the simplest problems in gravity, is led by easy stages throughout the whole range of experimental natural philosophy, as far as his attainments and capacity will permit. Adjoining the main room is a small dark room specially adapted and fitted up for optical experiments. Attached to the laboratory are a gas engine, three dynamos, and a set of seventeen accumulators so that an ample supply of current electricity is always at hand for lecture illustration or for laboratory experiment. The more valuable pieces of apparatus comprise a large spectroscope, polariscope, quadrant electrometer, optical bench, spectrometer, and various forms of galvanometers.

Mere mention must suffice for the large and valuable chemical laboratories, comprising two general ones, one technical and one metallurgical one; and the well filled library, with reading and reference departments in each of the two main buildings. One fact should be referred to as showing the success which has attended the labors of professors and students, and that is that since 1883 the number of Whitworth Scholarships, Royal Exhibitions and other prizes gained by students numbers no fewer than fifty-eight, representing a money value of over £6000.

MODERN GAS AND OIL ENGINES

By Albert Spies, Mem. Am. Soc. M. E.

Seventh Paper.

THE methods of igniting the working charges in gas and oil engines are details of design to which considerable study has been given without, however, having brought about anything like uniformity of practice. No one particular device, as was to be expected, has been centered upon as the best or most desirable one, and recurrence to the descriptions of engines already given in the preceding papers will show that electric ignition, flame ignition and ignition by incandescence all have found a share of favor in the eyes of gas engine builders. Electric ignition has been practiced either by the spark method, as in the early Lenoir engine, in which, at the proper times, an electric spark was made to pass between two electrodes within the cylinder, or by the incandescent wire method, in which an electric current was applied directly to heat a thin platinum wire. This latter method would appear to have been used only in an experimental way. Still another electric arrangement has been suggested a number of times, by which an electric arc was to be maintained in the cylinder of the engine, between two heavy platinum points, but this device, so far as can be found, simply figured in patent specifications, and never came into actual use.

The flame method is currently employed in many good engines of the present day, and was put into its first practical shape more than fifty years ago, since which time it has undergone a variety of modifications. With the early non-compression engines, in which the pressure in the cylinder before explosion of the charge was the same as, or even less than, the pressure of the atmosphere, flame ignition was a comparatively simple thing, and it was easy enough to transfer a flame from the outer air into the interior of the cylinder with little, if any, trouble from extinction. In the early flame-ignition experiments the very simple expedient was adopted of providing a hole in the cylinder wall, which hole was uncovered by the piston after a portion of the stroke had been passed over, and the flame was sucked through it into the cylinder. The hole was either so small that no appreciable loss of pressure occurred upon explosion of the charge, or it was covered by a small valve which closed automatically as soon as the pressure in the cylinder rose. When the gases to which the flame was to be communicated, however, were under a pressure of some magnitude, as is the case in nearly all the gas engines of the present time, the difficulties of the ignition problem were at once increased. The method just referred to, and not inaptly termed the "touch-hole" method, obviously became inapplicable, and special valve devices had to be designed to meet the new conditions, a good example of one of them being that of the earlier Otto engine, as illustrated in the first paper of this series.

Ignition of explosive gas and air mixtures by contact with more or less highly heated metallic surfaces, or the hot-tube method, as it is now generally termed, was suggested independently by several investigators a number of years ago. The general scheme pro-

posed was to ignite the gas and air charge by passing it through a metal tube heated to redness by a flame outside of it, and this method is in successful use to-day in a large number of engines. Wrought iron is generally employed for the tubes, though in a few engines platinum has been pressed into service, its higher cost being counterbalanced, in a measure, by its greater durability. A difficulty with the iron compressed air and gas charge to the tubes at the proper moment. The flame method and the hot-tube method just mentioned are the ones which seem to have secured the greater measure of popularity, being claimed, by their advocates, to be more certain in action and cheaper and simpler in arrangement than the electric devices. The latter, however, are by no means allowed to rest under any such imputations of com-

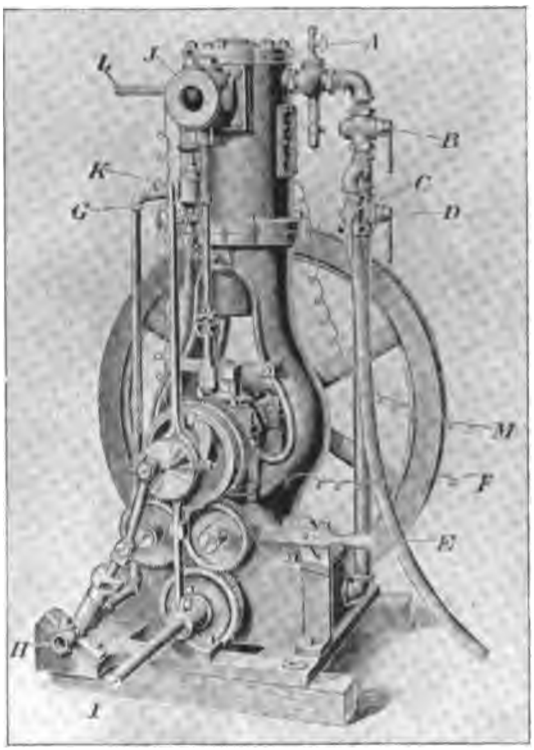


FIG. 98.-THE PACIFIC ENGINE—MARINE TYPE.

tubes is found in their rapid oxidation and furring, necessitating their more or less frequent renewal, but with their cheapness and the ease with which an old and worn-out one may be replaced by a new one, this objection is not so serious as might be supposed. In some engines the tubes are so screwed into the cylinders as to be constantly in communication with them, while in others valves are arranged which admit the parative inefficiency. A number of engine builders have devoted much energy to their development, and as a result this type of ignition device is now used with much satisfaction in some of the best engines on the market. A flexible electrode arrangement, which is employed in several of these devices, affording absolute certainty of contact in completing the electric battery circuit, is one of the most important im-

provements that has been made in connection with them, and to it is mainly due their present satisfactory action.

One of the forms of gas and oil engines, in which this arrangement is in

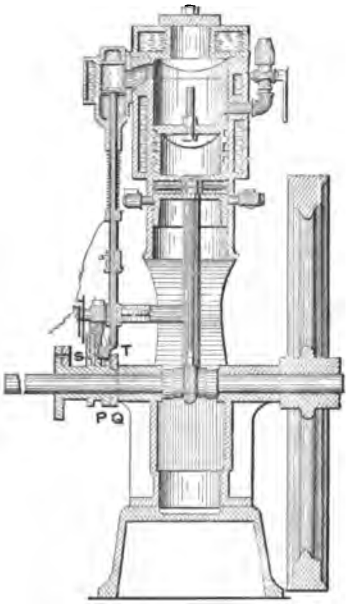


FIG. 99.—SECTION OF PACIFIC ENGINE.

use, and which has attained much popularity, especially for boat propulsion, is the Pacific engine, built both by the Union Gas Engine Company, of San Francisco, Cal., and the Globe Gas Engine Company, of Philadelphia. One of the earlier designs of this engine, arranged as a launch motor, with reversing gear and circulating pump for the cylinder water jackets, is shown in Fig. 98. In this *A* represents a relief valve, through which part of the compressed vapor may be allowed to escape to facilitate starting up the engine. The throttle valve is marked *B*, while *C* and *D* are gas and air regulating cocks; *E* is the reversing lever which, by being shifted from the upper to the lower position, brings a back gear into operation and causes the propeller shaft to run in a reverse direction; *G* is a clutch lever for stopping and starting the propeller shaft. The circulating pump *H* takes water through the bottom of the boat, and discharges it into the lower part of the water jacket around the cylinder, while the overflow pipe *L* from the upper part of the jacket is led out through the side of the boat above the water line. Water from the jacket may be drained off through the cock *K*. The coupling for connecting the engine with the propeller shaft is placed at the end of the secondary shaft *I*. The exhaust valve is marked *J*. The engine works according to the Otto cycle, and the charge, as previously intimated, is fired by an electric spark, *F* and *M* being the wires from the battery, the former connecting with an interrupting device, so that a spark is produced only at the beginning of every second down stroke of the piston. It will be understood that, like in the several other launch outfits,

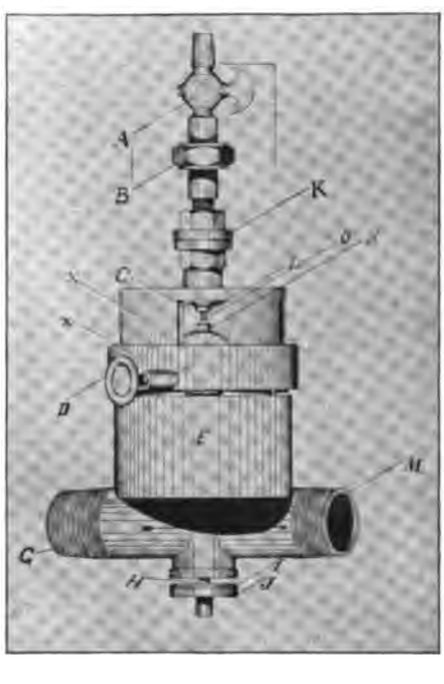


FIG. 100.—THE VAPORIZER.

described in some of the preceding papers, the engine itself is never reversed, but runs continuously in one direction, and the direction of motion of the propeller shaft and the secondary engine

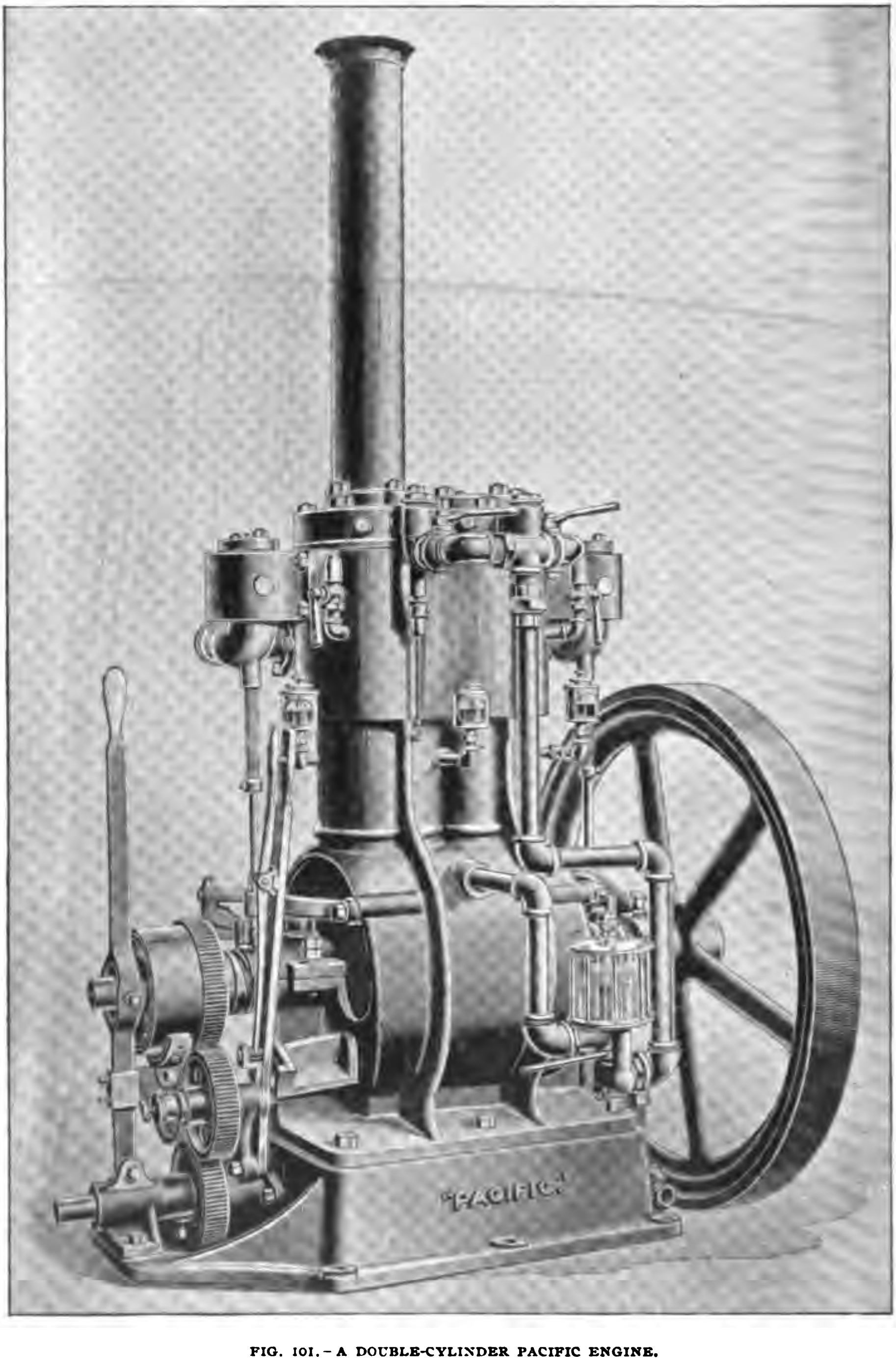


FIG. 101.—A DOUBLE-CYLINDER PACIFIC ENGINE.

shaft alone is changed, when desired, by the lever arrangement already mentioned.

The valve gearing of the engine, which is one of its special features, and entirely unlike that of any other engine in the market, is illustrated more clearly in the sectional view, Fig. 99. It will be noticed that on the crank shaft is a cam, *P*, having two grooves which run parallel part of the way around, and then intersect each other. A segment-shaped finger, *S*, rests in one of these grooves, and as the engine shaft revolves the finger is guided through the intersection from one groove to the other, and carries a swinging arm, *T*, under the exhaust valve stem once in every two revolutions. The cam *Q* at those periods lifts the arm *T*, and with it the exhaust valve rod, opening the valve and permitting the escape of the waste gases from the cylinder. The governor acts directly on the exhaust valve rod, holding it up, with the valve open, whenever the speed of the engine rises above the normal. The effect of this, to begin with, is that neither back pressure nor partial vacuum are created in the cylinder when running without working explosions, air from without being alternately drawn into the cylinder and expelled from it through the exhaust pipe. Admission of fresh gas and air mixture into the cylinder is, at such times, prevented simply by the fact that the exhaust passages are very large as compared with the gas and air inlet, and the exhaust valve, as stated, is held wide open, and there is thus less resistance to the flow of air through them than there is to the flow of gas and air mixture through its regular admission port and valve. The latter will, therefore, not open, and, consequently, no working charge can enter the cylinder until the governor catch on the exhaust valve rod is released by a falling-off in the engine speed and the exhaust valve is allowed to close.

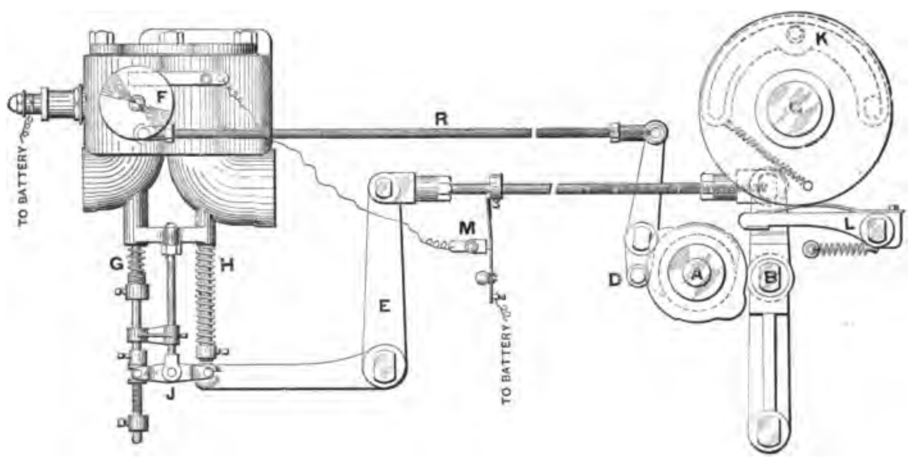


FIG. 102.—VALVE GEAR OF THE UNION ENGINE.

The design of the engine has latterly been somewhat modified, but only in details which but slightly change its appearance, the manner of operation remaining exactly the same. A double-cylinder engine is built on essentially the same lines as the one just described, and is shown in Fig. 101. This illustration also shows the improved form of vaporizer with which the engine is fitted when using gasoline, and which takes the place of the various forms of carburettors employed in connection with most other engines. The vaporizer is shown attached to the lower right hand part of the engine, at the side of the base near the fly-wheel, a detail view being given in Fig. 100. It consists of

either a glass or metal body *E*, glass being used in the one shown attached to the engine, and inside of this is a ball-shaped valve, *N*, seated on the end of a tube connected with the air inlet pipe *G*. Connection from the vaporizer to the engine cylinders is made at *M*. A casing around the exhaust pipe of the engine affords an annular space through which the air is drawn on its way to the vaporizer inlet *G*, and is heated by contact with the hot exhaust pipe. As the air enters the vaporizer body, it lifts the ball valve *N*, and the latter strikes against the spindle *O* of the gasoline valve, raising it and permitting a small quantity of gasoline to flow into the vaporizer through the cock *A*, from a conveniently placed tank at a higher level. The gasoline so admitted is at once turned into vapor by the heated air and is drawn off on its way to the engine through the connection *M*.

The lower end of the valve *N* is shown at *H* where a leather washer, *I*, is provided on a collar, *J*, the latter preventing the valve from lifting too high. The upper part *X X* of the vaporizer proper is arranged so that it may be revolved by loosening the screw *D*, enabling the attendant to observe the flow of gasoline through the opening, *C*, if desired, when starting the engine. The gasoline and air inlet valves *O* and *N*, of course, open only during the suction strokes of the pistons, remaining shut during the remainder of the working cycles. In actual practice this vaporizer has been found to perform admirably, and some preliminary trials made even with ordinary oils have been found to give promising results. The vaporizer being directly attached to the engine, and not a separate addition like the several currently used carburettors, makes the whole outfit comparatively simple and self-contained. The stationary Pacific engine is, in all essential details, the same as the marine type except that the reversing and clutch gears are omitted.

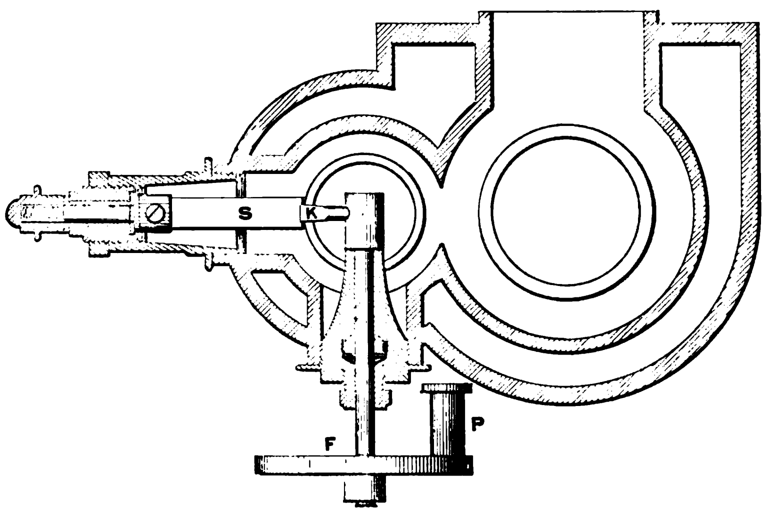


FIG. 103.—VERTICAL SECTION THROUGH VALVE CHAMBERS OF UNION ENGINE.

Another engine, of the horizontal type, however, made by the same builders, and known as the Union engine, is shown in Fig. 104. Details of the valve gear and igniting device are shown in Figs. 102 and 103, the former representing an arrangement slightly different in appearance from that seen in the general view of the engine in Fig. 104, but exactly the same so far as the manner of operation is concerned. Motion from the crank shaft *C* of the

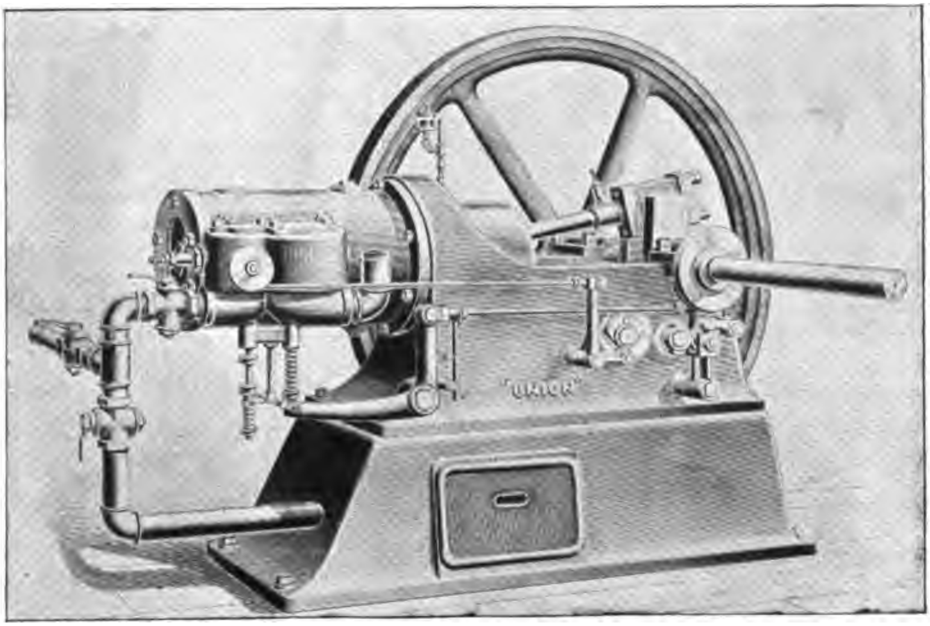


FIG. 104.—THE UNION ENGINE.

engine is reduced and transmitted to the cam shaft *A* through a series of intervening gear wheels not shown in the illustration, and the several cams on this shaft *A* operate on the cam rollers *B* and *D*, the former being on a rocker arm which works both the inlet and exhaust valves at the same time through a bell crank, *E*, while the latter is on another rocker arm controlling an electrode disc, *F*. The inlet and exhaust valves are designated by the letters *G* and *H*, respectively, and it will be easily seen that when one of these valves is closed, the other is opened, and vice versa, a small rocking beam, *J*, being interposed for this purpose.

Mounted on the engine crank shaft is also the governor with its restraining spring and weight, *K*, which latter, under the influence of excessive speed, moves outwards and, in the course of its revolution, depresses the catch lever *L*. The latter when so depressed hooks on to the upper end of the rocker arm *B* when the latter reaches its extreme right hand position, and keeps it there, with the inlet valve *G* closed and the exhaust valve *H* wide open, until the speed becomes slower and the governor weight again moves inward and no longer presses down the lever *L*.

As in the case of the Pacific engine, previously described, the exhaust valve, in virtue of this arrangement, is held open constantly while the idle strokes of the piston are being made, air being freely drawn into and expelled from the engine cylinder through the exhaust pipe during this period, so that there is no possibility of a partial vacuum being formed in the cylinder, or of back pressure being created.

The current interrupter for the electric igniting device is shown at *M*, and requires no special explanation as its manner of working is quite clear from the illustration. There is, it will be noticed, a flexible contact strip carried by a collar on the rod operating the bell crank *E*, and this strip, in moving back and forth with the rod in question, makes and breaks the electric contact at *M* at the proper periods which are determined both by the governor and by the nature of the reduc-

ing gearing between the crank shaft *C* and the cam shaft *A*.

A vertical section through the exhaust and inlet valve chambers, showing also the nature of the igniting electrode arrangement which is somewhat different from that used in the Pacific engine, is given in Fig. 103. The rod *R*, in Fig. 102, connects by means of the pin *P*, with the electrode disc *F*, seen in both views, and gives it an oscillating motion which, of course, is imparted also to the electrode *K* carried on the end of the electrode disc spindle. This electrode *K*, as will be at once understood, is thus made to alternately strike and clear the flexible electrode *S*, which is connected with one of the battery wires, and when contact is thus made and broken at this point, contact also being made at the interrupter *M*, in Fig. 102, a spark is produced which fires the explosive charge in the inlet valve chamber and cylinder. A four-cylinder engine of this type, with the cylinders placed opposite one another in two pairs, and with a modified form of valve gear has been built and has given particularly good results in point of steadiness of speed. The igniting devices described form subjects of several patents.

An English engine, which has achieved considerable prominence, is the Stockport engine, built by Messrs. J. E. H. Andrew & Co., Limited, of Stockport. In its early form it was of the double-end design—that is to say, there were two horizontal cylinders placed opposite each other, one being the motor cylinder proper, and the other, the compressor cylinder, and the crank was placed midway between the two. A number of modifications have, however, of recent years, been instituted in the design, so that, in one of its latest shapes, the engine is substantially like that shown in Fig. 105. In this, it will be observed, there is no separate compressor cylinder, and the

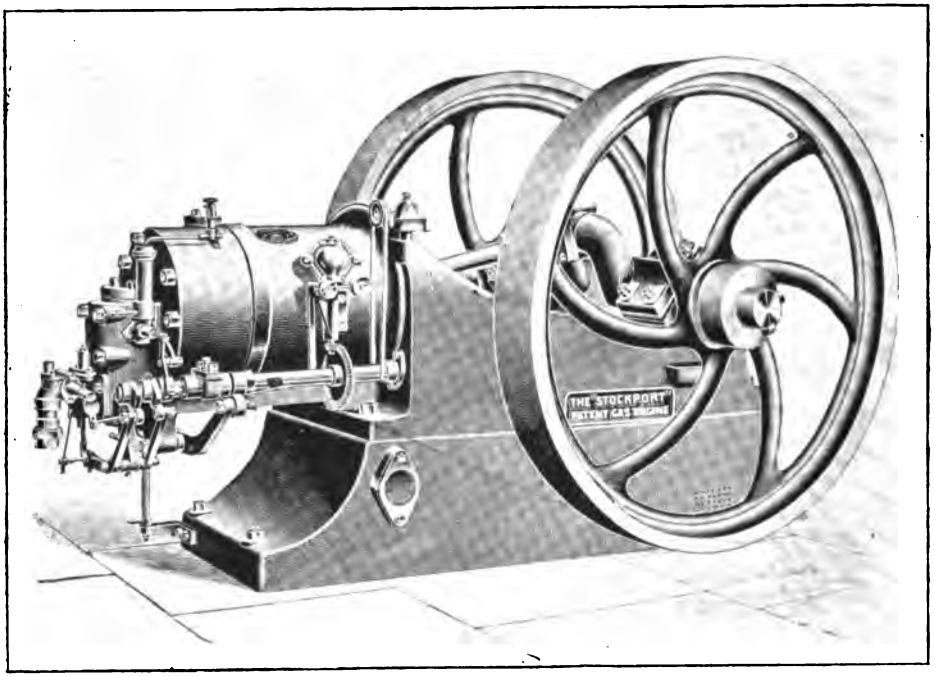


FIG. 105.—THE STOCKPORT ENGINE, BUILT BY MESSRS. J. E. H. ANDREW & CO., LTD., STOCKPORT, ENG.

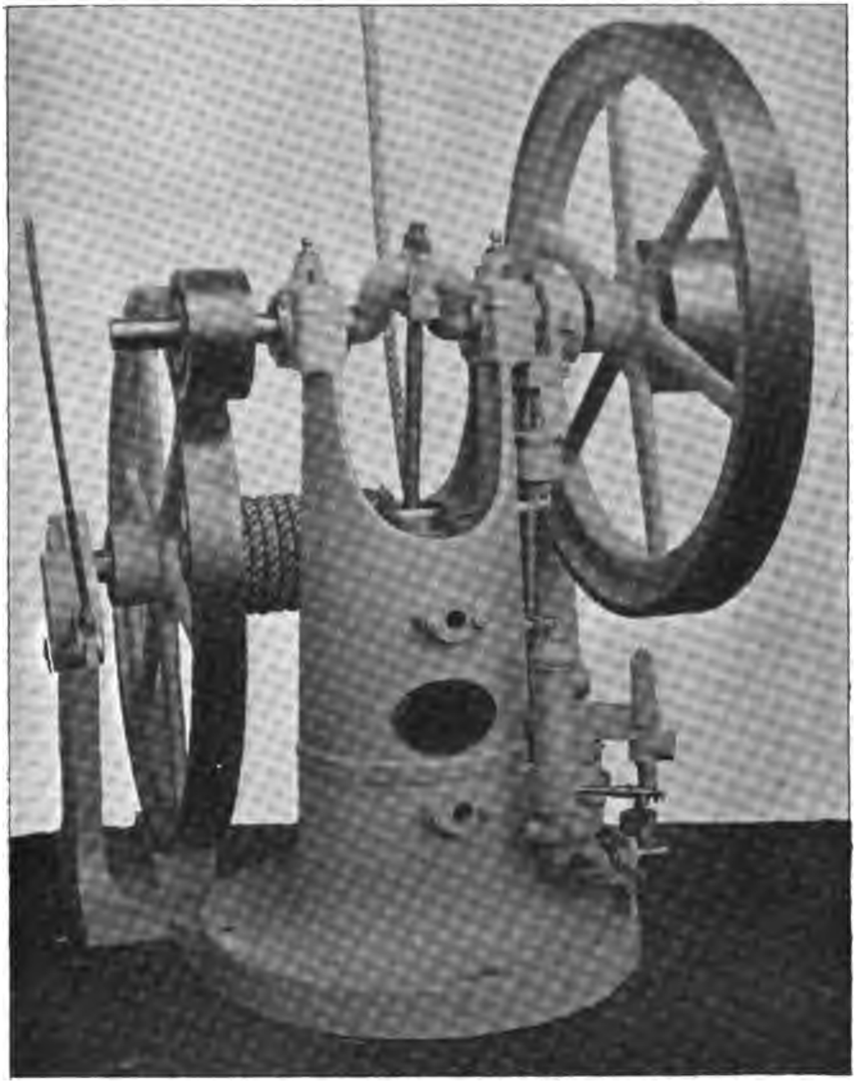


FIG. 106.—VERTICAL STOCKPORT ENGINE FOR HOISTING.

engine works according to the regular Otto cycle, with, normally, one explosion in every two revolutions. The valve gearing and governor are operated from a secondary shaft running along the side of the cylinder, and driven from the main shaft through intervening bevel gears. Firing of the working charge is accomplished by a tube igniter, and the valves all are of the poppet type. On the larger engines the type of governor shown in Fig. 105 is used, while the smaller sizes are provided with a vibrating governor shown on page 375, in which a weight, riding on a spring, is moved by a vibrating lever. So long as the engine runs at a certain speed the weight keeps in position a small hit-and-miss lever, and gas enters the cylinder of the engine. With any variation of speed above the normal, however, the posi-

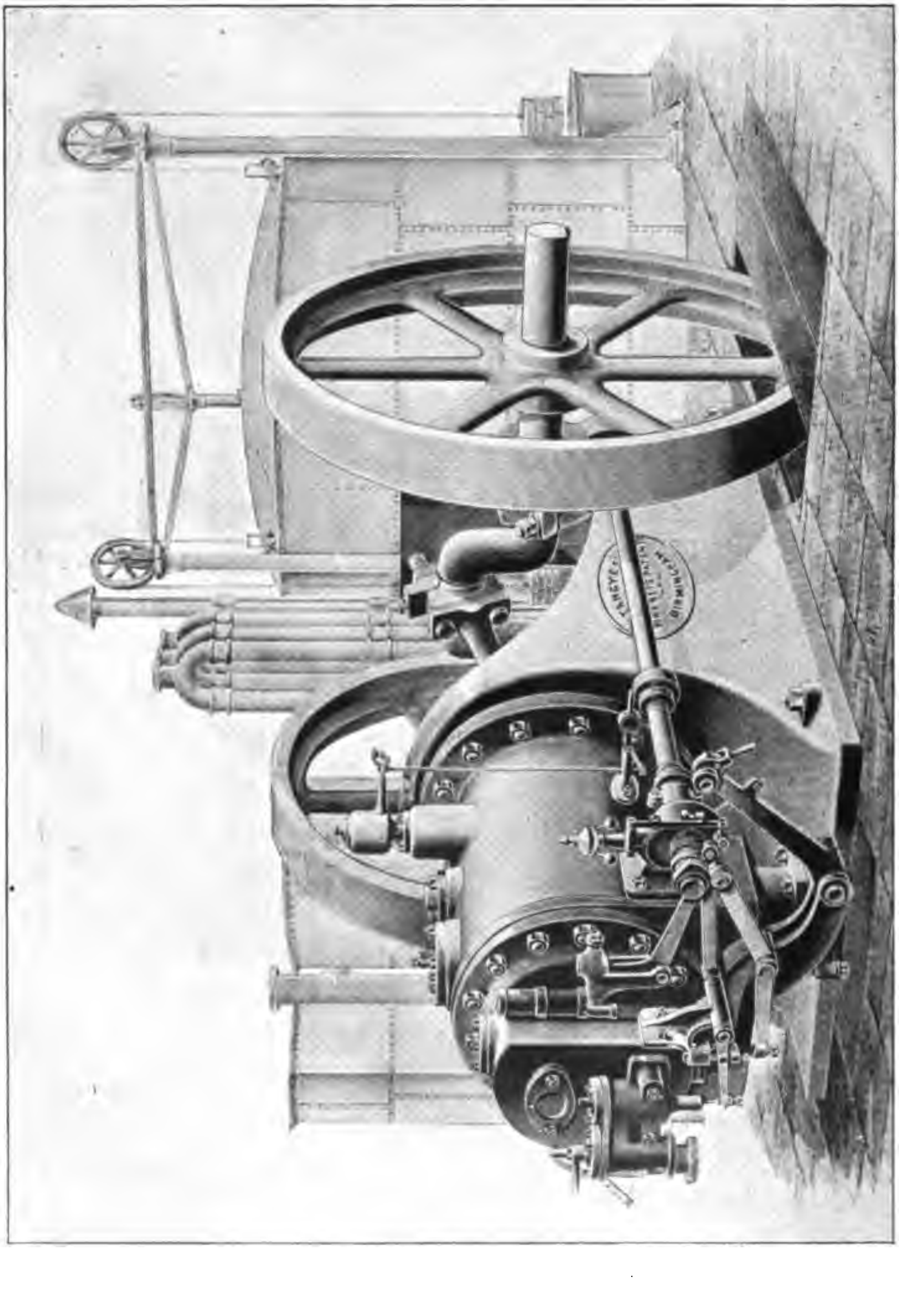


FIG. 107.—ONE HUNDRED INDICATED HORSE-POWER TANGYE ENGINE WITH GAS PRODUCING PLANT.

tion of the weight changes, moving the valve operating lever out of gear and cutting off the gas supply. For electric lighting and other work requiring very steady motion, a special governor is used for varying the explosive mixture, so that the speed may be controlled without missing explosions in the cylinder.

Messrs. Andrew & Co., who, by the way, are, next to Messrs. Crossley Bros. of Manchester, England, probably the oldest firm of gas engine builders, are the makers also of the Bisschop engine—an engine which will probably appeal only to the smaller power users, being a surviving form of the early non-compression type of motor which has been almost completely driven out of the commercial gas engine field by the developments of recent years. In this engine the principal end aimed at is to get a small, workable engine with the least possible complication, economy of gas being a secondary consideration. Instead of having a water jacket, the cylinder has cast on it a number of radiating ribs, which carry away the heat of the explosions and keep the temperature of the cylinder walls at a reasonable point. The cylinder is vertical, the piston rod and its connections extending upward, and motion from the crosshead being imparted to the crank by a vibrating lever arrangement. In order to prevent sticking of the piston in the cylinder owing to the rather high temperature which it attains, it is fitted quite loosely without rings, and the pressure from the gas explosions is so slight that the leakage past the piston is not serious. The flame ignition method is used to fire the charge, the flame being drawn into the cylinder through an opening in its walls on the already mentioned "touch-hole" principle.

In the matter of size of engines it is interesting to note that Messrs. Andrew & Co. are now building Stockport engines indicating as high as 150 horse-power in a single cylinder. One of the largest gas-driven electric light installations in England, at Morecambe, was equipped with engines by them, the plant comprising three Stockport engines of sixteen horse-power each, a Dowson gas plant, and three dynamos of 300 lights each, besides a storage battery outfit. Messrs. Tangye, Limited, of Birmingham, and Messrs. Crossley Bros., Limited, of Manchester, England, also have turned out noteworthy engines of large size, developing from

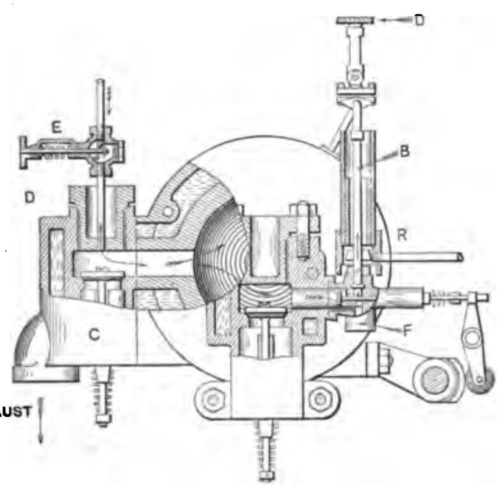
EXHAUST


FIG. 108.—SECTION OF END OF CYLINDER OF STOCKPORT ENGINE.

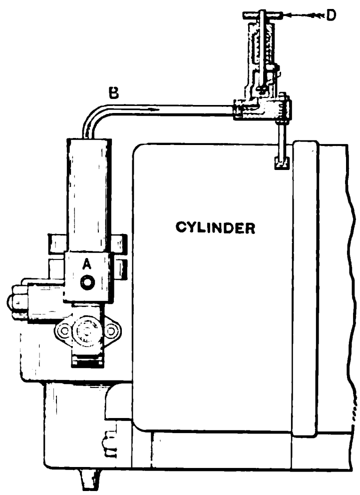


FIG. 109.—SIDE VIEW OF STOCKPORT ENGINE STARTING GEAR.

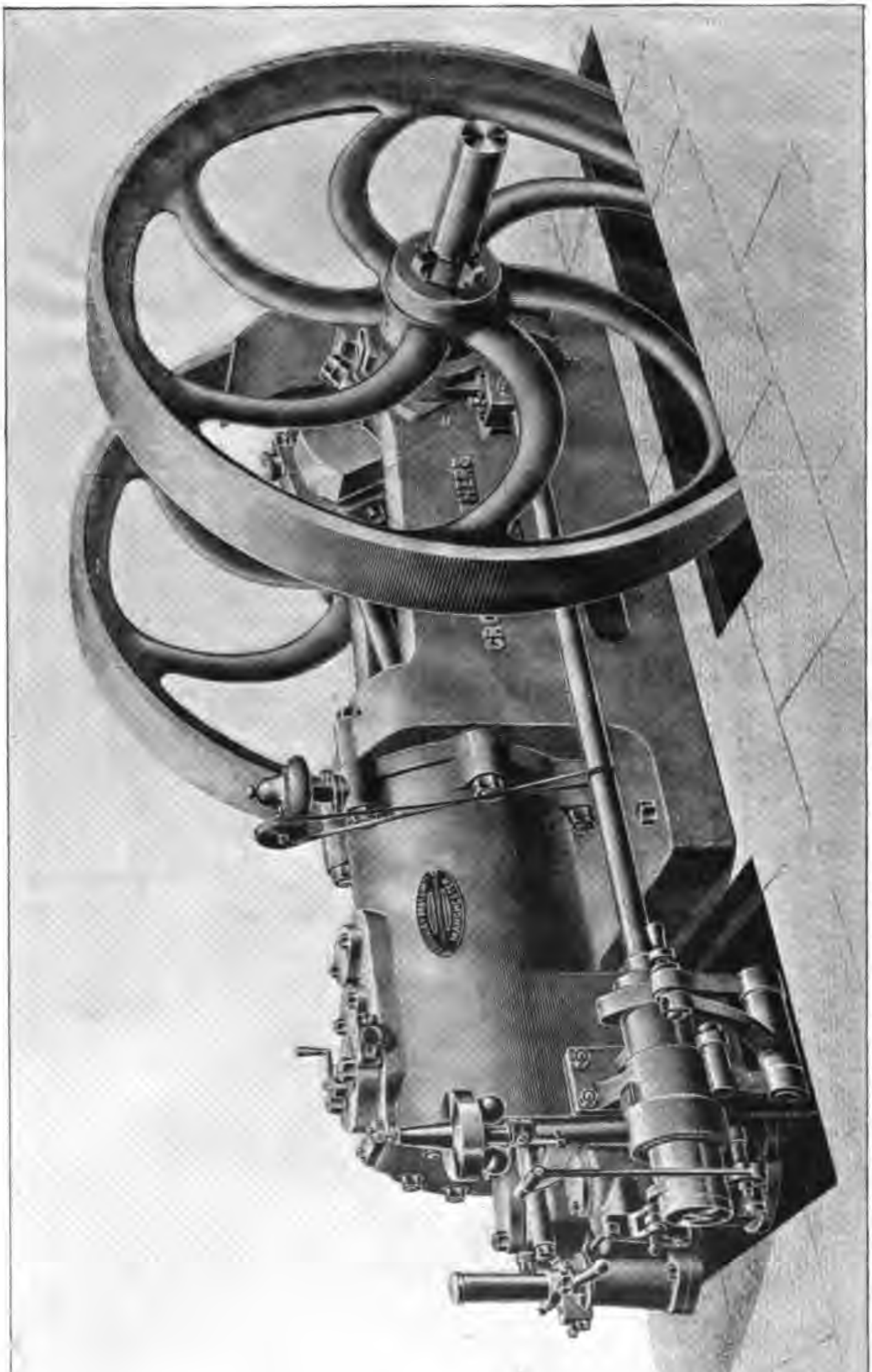


FIG. 110.—A ONE HUNDRED INDICATED HORSE-POWER CROSSLEY-OTTO ENGINE.

eighty-five to 100 actual horse-power. One of the Tangye engines, rated at 115 indicated horse-power, furnishes power for fine weaving machinery in a Belfast mill, and is stated to give eminent satisfaction, both in point of economy and steady running. The Crossley-Otto engine is, in the main, similar to the Otto engine made in the United States, and already described in the first paper of this series, so that it is not necessary to enter into its details here.

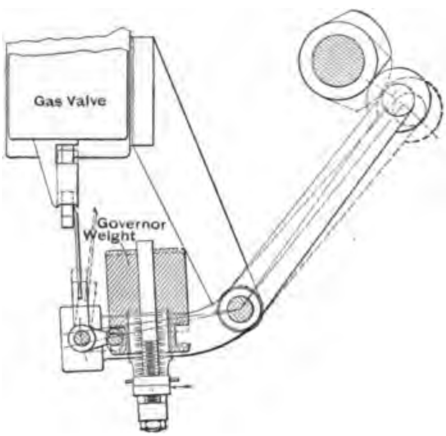


FIG. 111.—VIBRATING STOCKPORT GOVERNOR.

In nearly all the larger sizes of gas engines some form of starting device is now used which dispenses with the necessity of turning the fly wheels by hand —a proceeding which is not only difficult, but, in some cases, would be quite impossible. Of these starting gears that used by Messrs. Andrew & Co. on their engines is shown in Figs. 108 and 109, the former representing a side view, and the latter a sectional view of the end of the cylinder. At *A* is a Bunsen burner for heating the ignition tube *B*. At *C* is the exhaust valve, and above it a gas admission valve *E*. Above, and at the outer end of the ignition tube *B*, is an air outlet valve, with handle *D*. At *F* is a timing valve for fixing the period at which the gaseous mixture shall be admitted to the ignition tube. When it is desired to start the engine, the gas admission valve *E*—over the exhaust valve *C*—is opened. Gas commences to flow into the cylinder, which then contains only air at atmospheric pressure. This air is allowed to escape in quantity equal to that of the gas admitted by the valve at the end of and above the horizontal part of the ignition tube *B*. As soon as sufficient gas has in this way flown into the cylinder to produce an explosive mixture where it enters into the ignition tube, ignition takes place and the engine starts. The valve *E* and the air outlet valve are then closed, and the gas main, which had been previously closed, is opened and gas allowed to flow into the gas bag.

Messrs. Tangye's self-starter consists mainly of an air pump worked by hand, by means of which the space behind the piston may be filled with gas and air under a slight pressure. Some of this mixture enters the ignition tube and is fired, giving the initial impulse, after which the engine continues running in the regular way. Messrs. Robey & Co., of Lincoln, England, to whose engines reference was made in the July number of this magazine, use on their large engines what is known as the Clerk-Lanchester starter, illustrated in Fig. 112. It consists of a chamber *A*, outside and separate from the engine, and of a capacity rather greater than that of the cylinder, with which it is connected by a pipe *E*, and check valve *W*. The crank being set

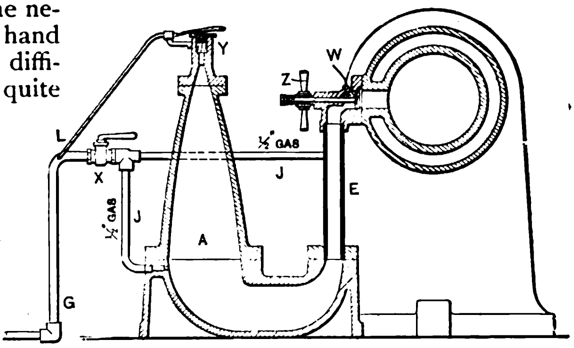


FIG. 112.—THE CLERK-LANCHESTER STARTING GEAR.

at about fifteen degrees, gas is turned on by a tap *X*, from the gas main *G*, and it flows into the chamber by the pipe *J*, mingling with the air therein and forming an explosive mixture. At the same time gas flows into the cylinder by the pipe shown. When the mixture is so far formed as to be inflammable, it lights at the jet *Y*, and a little later becomes of sufficient explosive strength. The tap *X* is then closed, and the ejecting pressure ceasing, the flame at *Y* shoots back, ignites the gaseous mixture in the chamber, and this forces the gas in *E* into the cylinder under a pressure of about fifty pounds per square inch, and forms there a compressed mixture which, on ignition, gives an average pressure in the cylinder of about eighty-five pounds per square inch, and starts the engine and its load. In the line ot petroleum motors Germany would appear to have kept well abreast of other countries, and a number of German makers have established agencies outside of their own domain, notably in England, for the sale and general

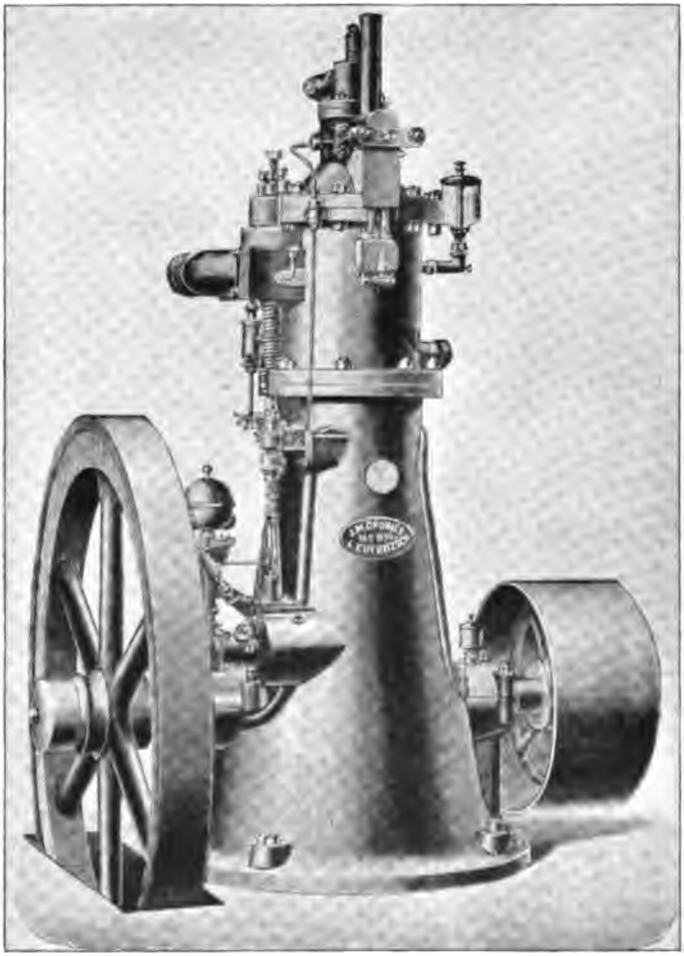


FIG. 113.—OIL ENGINE BUILT BY MESSRS. J. M. GROB & CO., LEIPSIC-EUTRITZSCH, GERMANY.

advertisement of their product, competing, thus, directly with a host of other engines in their own territory. Among these is the firm of J. M. Grob & Co., of Leipsic-Eutritzsch, who are building an engine which in Germany, at least, seems to be well known, and to have found considerable favor for all kinds of work—marine, stationary and portable. It appears, in fact, to be a modification of the Capitaine engine, already described in one of the earlier papers of this series.

Though on the market for only about two years and a half, something like 1400 of these engines are said to be now in use. The sectional view clearly explains the working mechanism. The engine belongs to that class of petroleum motors in which the oil is vaporized in a heated chamber before being drawn into the working cylinder, the vaporizing chamber being marked *V* in the illustration. Working, as the engine does, on the Otto cycle, it draws in air on its first down-stroke through the valve *A*, and petroleum through the atomizer *S*, the petroleum spray being vaporized in *V* before it mixes with the fresh air and enters the working cylinder. The vapor and air mixture is compressed on the next up-stroke of the piston, the air and atomizer valves closing automatically, and explosion of the charge at the beginning of the second down-stroke of the cycle is produced by some of the mixture having been forced into hot vaporizer, which serves the purpose of an ignition tube. The working stroke having been performed, exhaust during the second up-stroke of the piston takes place through the valve *E*, which is worked by a long shaft receiving motion from the crank shaft of the engine through intervening gear wheels. The valve rod is not connected to the exhaust valve, but simply strikes against the valve spindle and pushes it upward, the seating of the valve being effected by a spring. The valve is opened only once in every two revolutions of the main shaft. Heating of the vaporizing chamber is effected by the lamp *L*, and cooling water for the cylinder jackets enters and escapes through the connections *WW*.

The oil pump *P*, which supplies oil to the vaporizing chamber, is controlled by the governor in such a way that the amount is varied in accordance with the demand for power. The oil used is of the ordinary kind burned in lamps for illuminating purposes.

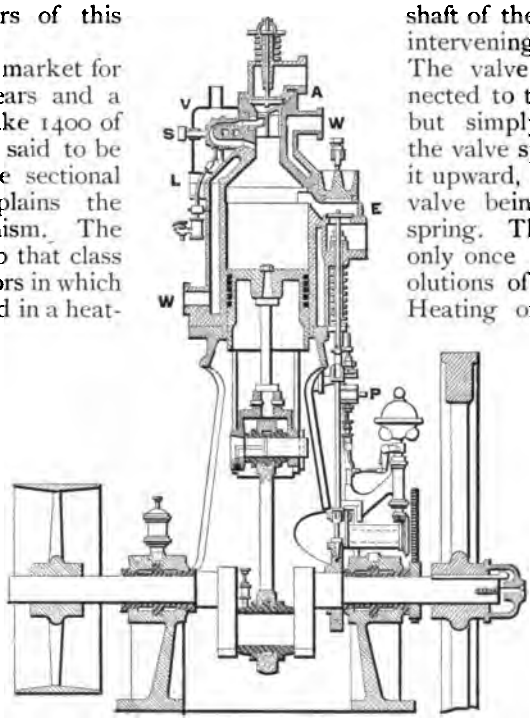


FIG. 114.—VERTICAL SECTION OF THE GROB ENGINE.

(*To be continued.*)

RECENT IMPROVEMENTS IN WATER VALVES.

By John Richards, Mem. Am. Soc. M. E.

THE drawings from Fig. 1 to 5 show some water valves invented by Mr. C. I. Hall, of San Francisco, Cal., and employed by the Cahill & Hall Elevator Company, to hoisting or elevator machinery, in their practice.

These valves were aptly described by the inventor in one of his first specifications as permitting the water to flow only in the direction intended, which is the leading characteristic of all the designs.

The company are makers of "hydro-steam" elevators, in which the impelling force is steam pressing upon the water, which actuates the hydraulic pistons, the water by reason of its inelasticity performing the required function of positive movement and "abutment," the same as in the case of common hydraulic elevators. The direct steam pressure dispenses with pumps, accumulators and so on, such as are employed when the price of water does not admit of its use from the public service.

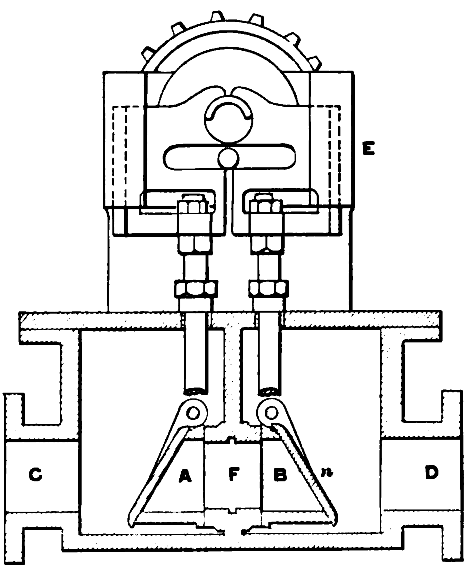


FIG. 1.

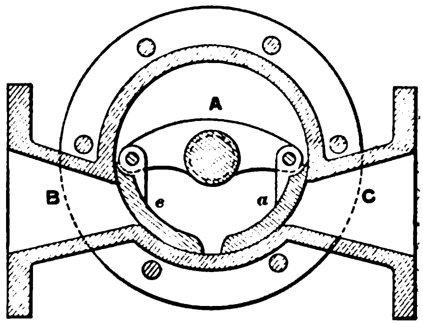


FIG. 2.

The water employed in the hydro-steam system, while inelastic in itself, does not produce regular or safe movement when controlled by common stop valves, for the following reason: Suppose, for example, a load is being raised, and the cage is stopped on the way to receive an additional load, as in the case of passengers getting on at the different floors of a building. When the cage is stopped there is an equilibrium between the load and the steam pressure acting on the water, but when the valves are opened to go on, or to go down, the static pressure will be insufficient to sustain the new load, and the cage will suddenly drop until the steam rushes in to check the back-flow of the water and balance this added load. For this reason common stop valves cannot be employed.

In the case of removing a part of the load during a trip of the cage the same difficulty occurs. The pressure at the time of stopping the cage remains in the steam receiver, and when valves are opened this force is too great for the reduced load, and the cage is suddenly shot upward until the forces are balanced. The present valves are em-

ployed to prevent this false movement, which occurs in the case of both passengers and goods.

Fig. 1 shows the form of water valves first applied to the hydro-steam elevators. *A* and *B* are two sliding valves operated by the mechanism at *E* so that either can be raised, the other remaining stationary. These valves are

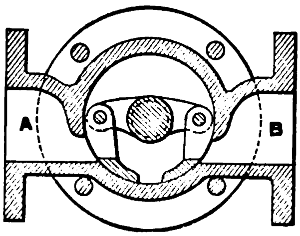


FIG. 3.

open the same as the passage *F*, but have on their outer faces two hinged plates *n n*, as shown in the drawing, that are free to open outward when the valve to which they are attached is opposite to, or covering the port *F*.

Assuming that the water is to flow from *C* to *D* to cause the elevator cage to ascend, and that an additional load has been taken on. The valve *A* is then opened, but no back flow can take place from the elevator ram or piston through the valve *B*, because of the hinged cover *n* forming a stop in that direction, but as soon as the pressure through the passage *C* equals that in the passage *D* then the plate on the valve *B* raises automatically, permitting free flow from *C* to *D*. In other words, the elevator cage stands locked and still until the pressure balances the new or increased load, and then starts on the same as if no elastic medium was employed. The same thing occurs if the cage is ascending or descending. When the valves are in the position shown in the drawing they constitute a simple stop valve, preventing flow in either direction.

This form of the valves has been displaced by that shown in Fig. 2. Two hinged plates *a* and *e* are mounted on an oscillating bar *A*. When this bar is depressed at either end it opens the corresponding passages *B* or *C*, but no flow will take place either way until there is an equal pressure at *B* and *C*. In the position shown the valve stops flow in either direction the same as in Fig. 1. The functions are quite the same, but the difference in cost is as one to three in favor of the valve last described.

The valve shown in Figs. 3, 4 and 5 seems at first glance to be the same thing, but it is quite different in operation, and for a different purpose altogether. It is called an automatic stop valve, to check the flow of water to the piston or ram of an elevator at the extremes of the stroke, and is employed in connection with a main valve, such as shown in Fig. 2. It will be noticed that when this valve is in its central or neutral position, as in Fig. 3, it is just the opposite of the one Fig. 2, being open both ways, offering no obstruction to flow in either direction, but when set, as in Fig. 4, it becomes the same as the one shown in Fig. 2, open to flow in one direction only.

Actuating tappets or stops of some kind on the elevator cages turn the valve to a close, right or left, at the extreme of the stroke, as seen in Fig. 4, so the main valve need not be disturbed until the cage sets out on a new trip. With a common valve there would be

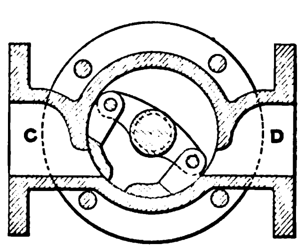


FIG. 4.

no way to start back again; here, however, as soon as the main valve is opened the stop one is thrown into the position shown in Fig. 5, and when the tappets or stops that closed the valve are released it is returned by a weight or spring to the position shown in Fig. 3, ready to act the other way.

The hydro-steam system of operating hoisting and lowering machinery, employing in combination an elastic and inelastic fluid, gives rise to a num-

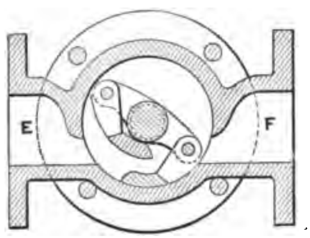


FIG. 5.

ber of problems of much interest, these valves being one, others may be dealt with in a future place. The subject is left here, first calling attention, however, to the valves in Figures 2 and 3 as mechanical expedients. It will be noticed that the rubbing surfaces operate under conditions that will keep them tight, and that no non-corrosive metal is required, unless it be the stems that are packed. The cost is only one-third as much as that of any of the common forms of stop valves, and the peculiar functions are thrown in gratis, so to speak.

We know of only one example that excels these devices in cheapness of first cost, and yet is good and serviceable ; that is the irrigation valves, as they are called, employed in Southern California, and shown in Fig. 6.

The main chamber *A* is rectangular in its middle section, the whole cast in one piece, with an oblong spout *B* at one side, a hand-plate *C* at the other side, and a nipple *E* to receive the water pipe *F*. The valve *D* is rectangular to prevent its turning in the case *A*, the face being made of leather riveted to a thin metal plate that slides in grooves in the bottom of the valve. The screw is held in the valve by a small pin *a*, and when this is removed the valve can be taken out through a hand-hole *C*, the main part of the water in the mean time flowing out at the spout *BB*.

Scores of these valves are required on a large ranch or fruit farm, and are quite as convenient and durable as the common kind that costs four times as much. This is a kind of machine design calling for the highest ingenuity, seldom recognized as skillful. Praise is reserved for more complicated and expensive things.

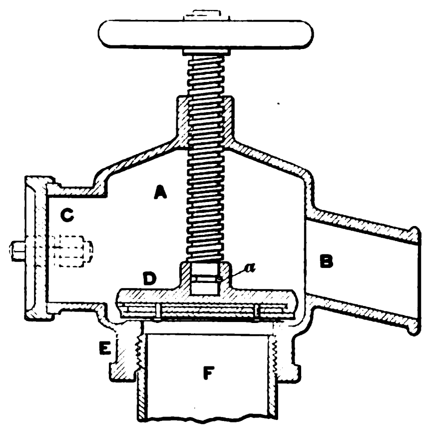


FIG. 6.

THE LIFE AND INVENTIONS OF EDISON.*

By A. and W. K. L. Dickson.

Eleventh Paper.

THE extension of factories enlisted a large amount of Mr. Edison's personal attention. Of these, the Goerck street shop at New York was the initial enterprise, supplemented by a smaller manufactory at Menlo Park, flanked by auxiliary establishments for the purpose of promoting underground tubing, an important outcome of the system, incorporated under the name of the Electric Tube Company, and of which the city of Brooklyn furnished the first harborage.

In laying the first Metropolitan telephone wires under ground on the Edison ante-induction system, each tube contained from two hundred and fifty to four hundred wires. At every twenty feet a box was placed for the purpose of breaking up the induction, which was done by separating the wires, and not allowing them to remain side by side in the next length of tubing. This was contemporaneous with the administration of Mayor Grant, of New York city, which rendered itself conspicuous in the ensuing year by requiring the removal of all overhead wires.

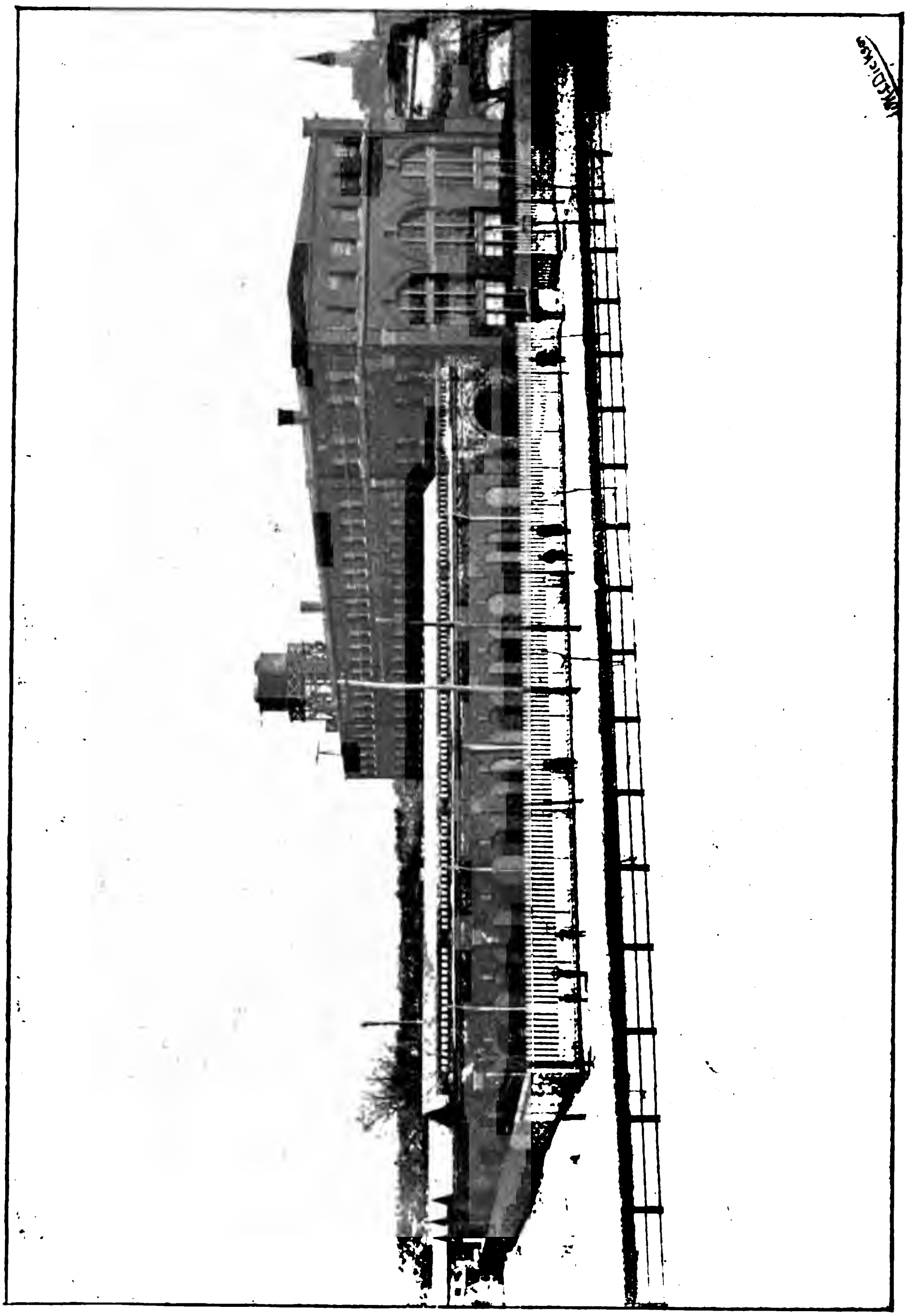
The demand for isolated plants was steadily on the increase, heralded by the installation of the first commercial incandescent lighting plant in the mill of James Harrison at Newburgh, N. J. So extensive and widely segregated were the demands for isolated plants, that it was found necessary to create a separate company for the sale and supervision of these industries. This organization was launched in 1881 under the title of the "Edison Company for Isolated Lighting." A common source of creative energy was supplied to these isolated plants by the establishment in 1882 of the Pearl Street Central Station at New York city, with fifty miles of conductors and 2000 lamps. The practical workings of the Pearl street station were remarkably facilitated by Edison's invention of the three-wire system, and the central business was rapidly extended into a number of auxiliary stations.

The Goerck street shop expanded with its growing necessities, and signalized its rise in the social scale by the assumption of the more imposing title, "The Edison Machine Works." A large factory at Newark, N. J., became the birthplace of the "Edison Lamp Company," a corporation formed for the purpose of exploiting the completed lamp, and extended later into the "Lamp Works of the Edison General Electric Light Company," at Harrison, N. J.

Marked prosperity has attended the Newark enterprise, which is in existence at the present time, its capacity amounting to over 25,000 lamps per day.

Sigismund Bergman, a maker of electrical instruments, held a license from the company, embracing the manufacture of sockets, fixtures and similar appliances, and under his skillful and energetic management the factory at Avenue B and Seventeenth street in New York city was added to the business, with a force of several hundred hands, afterward increased to over a thousand, and backed by the important establishment at Twenty-seventh street and First avenue. In 1886 the Edison Electric Light Company and the Edison Company for isolated lighting consolidated under the name of the Edison Electric Company, an offshoot of which was sup-

* Began in November issue.



THE EDISON LABORATORY AT ORANGE, N. J.

plied by a coalition of manufacturing interests known as the Edison United Manufacturing Company, an organization resembling the old Isolated Company, but gifted with influence and territorial powers immeasurably in advance of its predecessor. Still the course of public events pointed to the necessity of a supreme and central focussing point which was attained in 1889 by the consolidation of the various light and power industries under the title of the Edison General Electric Light Company, with a capital stock of $15,000,000 and a gross annual business of nearly the same amount. From the parent stream, represented by the magnificent headquarters of the organization in Broad street, New York city, radiate, amongst many others, the following giant tributaries: The numerous buildings for the exposition of the completed lamps and fixtures located on Fifth avenue, the colossal factories in the different portions of the same metropolis, the branch offices in Boston, Chicago, Toronto, San Francisco, Portland, Denver and Atlanta and the enormous manufacturing centres in New York State, notably the important establishment at Schenectady, together with the buildings in Harrison, N. J., and Peterborough, Ontario.

In the year 1891 the parent establishment on Broad street, New York, gave employment to hundreds of clerks, comprised a list of 600 paying customers, and exhibited a monthly income and expenditure of $1,000,000. Ten million dollars was the showing of the last fiscal year in the way of aggregate business accomplished, and $4,000,000 are frequently embodied in the raw material in process of use. The aggregate of the Edison stations, large and small, embraced in 1891 the enormous total of 1,371,000 lamps, exclusive of the colossal amount supplied by the isolated plants, several thousand of which exist, with a capacity of from 5000 to 10,000 lamps, and necessitating many thousands of horse-power for car service alone. The electric railway department is represented by sales amounting to 27,679 horse-power of motors and 22,836 horse-power of generators in a single year, to say nothing of the multifarious uses which electricity affords, such as mill plants, mining outfits, electric elevators, dynamos for supplying telegraphic currents, stationary motors of different sizes and appliances. Within the last year the Edison General Electric Company, for certain business and political reasons, has effected a consolidation with the Thomson-Houston Company, and the amalgamation is now known under the imposing title of the General Electric Company of America. As the company now stands, it is the most stupendous organization of its kind to be found in the world, and its financial basis is at least five times greater than the combined capital of all the electric companies of America. In 1892 it boasted of a capital of $50,000,000, and with the income derived from the innumerable light and power industries using its apparatus, the yearly receipts were in the neighborhood of $40,000,000. The autocratic power wielded by this Titanic enterprise is marked even in this age of syndicates and monopolies. At the nod of this reincarnated god of the lightning, almost every electric light in America could be extinguished, leaving the country at the mercy of such outworn methods as gas and oil, for the company exercises its imperial sway over ninety-two per cent. of the electric lights in the United States and controls a corps of 60,000 employees.

A more interesting pilgrimage for devotees to electrical science could hardly be imagined than that afforded by a survey of the different industries, where the solution of the incandescent light may be minutely traced from its first mystic birth, through its successive avatars, until it attains its apotheosis in the artistic creations of the perfected lamp. With the crystalline bulb enshrining the luminous filament we are all familiar; few, however, have gauged the beauty and variety which have found embodiment in the setting and fixtures. These are indescribably lovely and lend themselves to every style of architecture from the buoyant charm of

a Louis Quinze salon to the mournful splendors of a Moorish palace. In one of these felicitous reproductions the ceiling of the banqueting hall is inlaid with arabesques of tinted crystal set in beaten gold, mellow bronzes and frosted silver, and a multitude of incandescent lights concealed within the gems, calls forth a kaleidoscope of prismatic rays. In another of these enchanted abodes, on the occasion of a bridal feast, a central group of wrought silver represented a gondolier plying his bark through a sheet of mimic water. By some automatic and synchronous arrangement, invisible to the spectator, the electric spark flashed to the edge of the oar whenever this was lowered into the waves, producing the exact effect of that phosphorescent radiance which the ocean emits.

At Mr. Edison's sumptuous residence "Glenmont," of which more hereafter, and on the occasion of a juvenile party in honor of the inventor's youngest daughter, Madeline, myriads of incandescent bulbs, stained in a variety of exquisite colors, were concealed among the crystal fringes and stalactites of the great chandeliers, and connected in such a fashion with the sources of electrical supply, as to throw out one after another, sheets of emerald, ruby, sapphire, amethyst and gold, after the manner of the illumination of St. Peter's at Rome. In the "Life Cake," a glittering creation of elfin towers and châtelaines, argent foliage and frosted bloom, was enshrined a single electric bulb, which glowed like the famous "Sea of Light" in a setting of minor gems, compounded of a fringe of tiny incandescent lamps not much larger than drops of dew.

On the stage the effects attained are indescribably beautiful. All will remember the presentation of "The Foresters" at Daly's Theatre at New York last year, the haunting loveliness of those fairy glades, dotted with the glow-worm lights, the starry diadems, the scintillating wands, the changing constellations of tinted fires.

There is scarcely a department in the varied kingdoms of nature and art which does not meet us in our æsthetic pilgrimage. Here the delicate radiance plays

> "All round the fragrant marge,
> From fluted vase and brazen urn,
> In order, Eastern flowers large,
> Some dropping low their crimson bells,
> Half closed, and others studded wide
> With disks and tiars."

Here it is dreamily suggested through the silvery spires of coral or the rose-lined recesses of ocean shells. Here, again, it breathes sulphurous through the inflated nostrils of an Eastern Afrite or mediæval dragon. Here, again, its radiance is centred in a lamp which might well be the counterpart of that wonder of the Neronian age, the flying Phœnix of Alexandrian Anthrax, the rose-hued twilight of which lent such an irresistible charm to the beauty of Agrippina. Here, again, emerging from the crepuscular dream of fair women, we are blinded by the effulgence of a Titanic coronal.

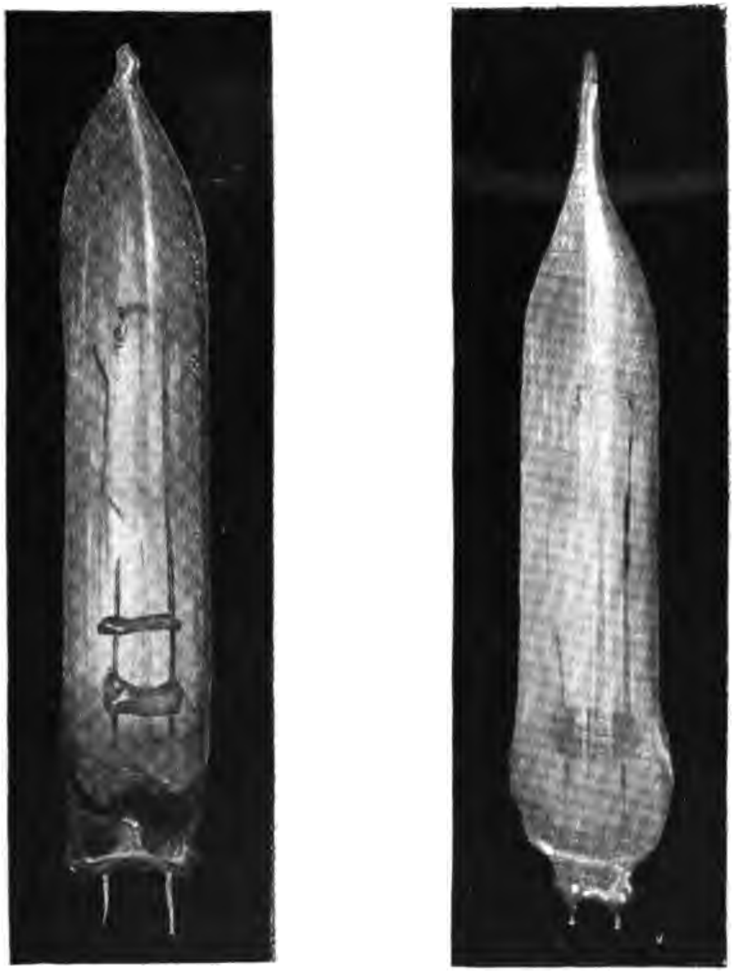
> "Upspringing arches of translucent pearl
> Bedded in frosted argent, richly dight
> With roods of starry diamonds, and bound
> The brows about with rows of milky fire."

But it is time to shake ourselves free from enchantment and to seek the busy highways of this work-a-day world.

As we already have had occasion to remark, Edison's career has brought with it the usual penalties of successful genius, but so inured has he become to the counter-currents of jealousy and detraction, and the ebbs and flows of fortune's tides, that he will extract a light hearted jest from the most virulent newswaper paragraph and peruse the decision of a protracted lawsuit without the moving of a muscle. Some people are launched into this hornet's nest of a world, with never a moral epidermis to dull the force of taunt and inuendo. The physical nerves, that subtle telegraphy of the body, flash the poisoned currents straight to brain and heart, and except the man shelter himself beneath armor from the Prince Immanuel's own treasury, he must needs be done to death by slanderous tongues. Others, again, seem provided with a crustacean

coating, in addition to the normal cutaneous equipment, from which the poisoned shafts of injustice glance harmlessly aside. To this order our inventor belongs. His philosophy, inherent and acquired, would scarcely discredit the founders of the platonic and stoic schools, and it is the more to be admired, from the fact that it exists side by side with warm affections and a genuine appreciation for the beautiful in nature and art.

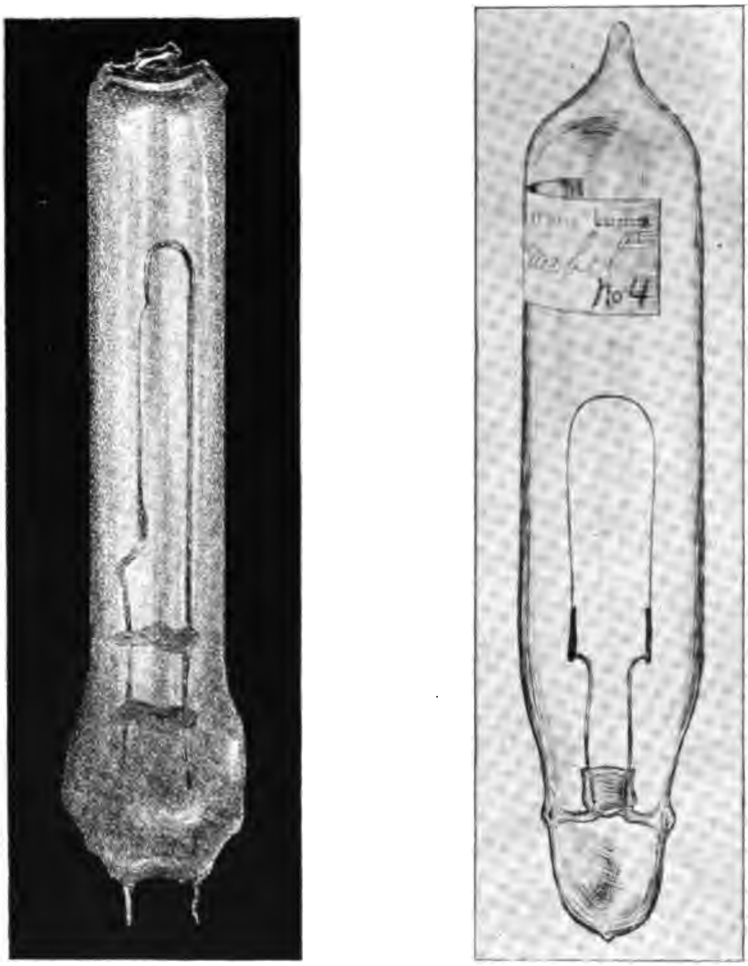
"As we were saying," litigation, fast and furious, has dogged the steps ot the inventor. It would tend neither to pleasure nor profit to chronicle the telephonic, telegraphic and illuminating contests in which he has engaged, and in which enormous fortunes have been involved. We will simply confine ourselves to a specimen sketch of the electric light litigation, in connection with which an important decision was reached in 1889. The issue involved was embodied in the broad wording of the patent issued to Messrs. Sawyer & Mann in 1885, claiming the rights over an incandescent conductor for an elec-



SOME ALLEGED EARLY GOEBEL LAMPS

tric lamp, composed of carbonized fibrous or textile material of an arch or horseshoe shape. The decision at the time was rendered in favor of Sawyer-Mann, but the question was revived with great vigor and acrimony four years later, in the famous case of Westinghouse vs. Edison. In the course of the controversy, which brought under survey the progressive stages of electric lighting and the relative merits of contestants, it was claimed by the defendants that the Sawyer-Mann lamp was inefficient and inoperative, the conductor having been made of a carbonized strip of paper, which immediately burnt out in any vacuum which it was then possible to produce. The argument was also advanced that the incandescent lamp became a commercial possibility only when Edison invented his subdivided system, and made it not only possible, but necessary to use, as the incandescing element, a fine thread or filament of carbon. It was claimed, moreover, that Sawyer & Mann were not the inventors of such a filament, and that their lamp, even with a perfect vacuum, could not be used in the Edison multiple arc system of lighting, their conductor being far too large for such use. The gist of the argument was that, inasmuch as the plaintiffs had failed to produce a practical lamp suited to commercial purposes, their patent was not entitled to cover methods which had proved of incalculable benefit to the social and commercial world. On the other hand, the complainants claimed to be the inventors of the fibrous conductor, the essential and operative feature of the incandescent lamp and denied the assertion of that lamp's brief duration, claiming that it had been tested and found to burn for 150 hours. In sifting this mass of conflicting evidence and in narrowing down the points of lighting which came within the lines of original invention, Justice Bradley denied priority to the several claimants as regarded the suspended glass globes, popularly known as incandescent lamps, averring that these had been in use in 1845 by King, in 1846 by Greener, in 1852 by Roberts, in 1872 by Konn, and in 1875 by Risloff and others. The court, moreover, held that the giving of an arched form to the light-making tape or wire within the glass chamber, called the conductor, had received its first application in 1848. The inventive principle under discussion, therefore, and the one to which the patented right would apply, lay in the extreme attenuation of the tape or filament and its enclosure in a perfect vacuum, such as the globe now affords,—conditions without which the present perfected incandescent lamp would have been an impossibility. The court, in its proceedings of October, 1889, conceded the priority of the invention to Edison, basing its conclusion on the fact that his patent ante-dated that of Sawyer-Mann by a period of one month. Justice Bradley's remarks contained a lucid presentation of the subject, and an emphatic recognition of the superior practicability of Edison's methods. So conclusive was his summing up, that it would have furnished a permanent settlement to the question, but for the fact that our laws are devoid of that immutability which marked the Median and Persian codes. Successive appeals were made to a scale of graded tribunals, the latest of which confirmed the favorable verdict of 1889.

Scarcely had matters been satisfactorily adjusted in this quarter, when the attention of Edison and his backers was drawn to the formidable claims of a German, Heinrich Goebel, of New York, advanced through the Beacon Vacuum Pump Company, of Boston. Sued for infringement of patent by the Edison General Electric Company, this organization boldly asserted that lamps, embodying the essential principles of Edison's incandescent, had been in process of construction since 1854, and were the discovery of Mr. Goebel, and that therefore the incandescent lamp patent should be considered void, for lack of originality,—an assertion which was further strengthened by an exhaustive review of the conditions of electric lighting, prior to the issuing of the Edison patent. In this connection,



THE FIDDLE-BOW AND HAIR PIN LAMPS.

the same ground was traveled over as we find in the suit—"Westinghouse vs. Edison" and the claims of prior invention at the hands of Starr, King, Roberts and others, were met as before with the unanswerable reply, that of all this multitude of investigators, Edison had alone succeeded in disclosing to the world a practical, commercial lamp, adapted for domestic uses. In this counter claim Edison was emphatically supported, as before, by the court.

"When," remarked Judge Colt, in the course of his summing up,—"we review the literature which preceded this invention, the subtle force with which it had to deal, whose laws had to be intelligently investigated and understood, the well-nigh perfect workmanship necessary in construction, and the slow steps by which the end was finally reached, it seems on its face almost incredible that the incandescent lamp of Edison was, in fact, invented and operated by Henry Goebel, in New York, forty years ago, and publicly exhibited before hundreds of people."

Goebel's story runs thus. A pupil of Professor Munchausen of Hanover, with whom he studied physics, experimented extensively in the construction of galvanic batteries, and the gen-

eration of electric light, in process of which he became exhaustively familiar with the principles of arc lighting, and with the methods employed by Edison's predecessors. Pursuing this line of thought many valuable ideas occurred to him regarding the incandescent light, and he arrived at the conclusion that an incandescent lamp could be produced by. a small continuous carbon, enclosed in an exhausted glass tube, hermetically sealed. These principles received practical application immediately upon his arrival in New York, where he established himself in 1848 as an optician and watchmaker. The first form of incandescent lamp which he constructed, was called a "fiddle bow," and consisted of an exhausted tube, made of glass, in one piece, with leading wires sealed into the enclosing chamber by fusion of the glass. The name is suggested by the shape assumed by the wires with the carbon burner attachment. The next style evolved, was termed the "hairpin," from the form given to the carbon. A third shape, presenting carbon and connecting wires in a straight line was abandoned as unsatisfactory. Leading wires of platinum, iron and copper, entered into the construction of these lamps, and the carbons used were made of flax, reed and black cane, one hundredth of an inch in diameter. Attempts were made to secure perfect vacuum by means of an ordinary air-pump, but these failing, comparatively good results were secured by filling up the tubes with mercury, inverting them, and sealing the ends after expelling all superfluities. Prior to the sealing process, the incandescent conductor had been slightly heated, which, together with a little shaking, caused the mercury, adhering to the carbon to fall off. The ends of the leading wires were flattened, then twisted into a spiral tube, into which the ends of the carbon were inserted, and the tubes were then compressed. The joints were generally cemented with heated stove polish, though sometimes the ends of the carbon were electroplated with copper, and an amalgam of gold and mercury was applied to the joints, which adhered to the copper. Sometimes, moreover, a platinum sponge was used for this purpose, the electric current being produced by chemical action from batteries.

Goebel claimed that the utmost publicity was given to the "fiddle bow" and "hair pin" lamps between 1850 and 1880, that these were on exhibition at Cooper Institute, Union square and at his own house in Grand street at New York; that the principles evolved were original, and that he was in total ignorance of Edison's methods, being debarred from outside commuuication by his defective knowledge of the English language. He further claimed that the merits of bamboo, as a basis for carbons of platinum for leading in wires, and stove polish as a cement, had been recognized by him, prior to the year 1872, and that lamps, embodying these improvements, were made and burnt during this period. The existence of the perfected form is based entirely on the evidence of Heinrich Goebel and his son. The other affidavits, some forty in number, embracing the testimony, relative to the old fiddle bow lamp, and covering the years ante-dating 1860, emanate from Goebel's friends, and while these may possibly be colored with personal feeling, the character of the witnesses seems trustworthy. In reviewing the successive stages of the Goebel lamp, Justice Colt drew attention to the earlier form, embodying the ideas contained in Starr's old lamp, with its carbon pencil, enclosed in a Torricellian vacuum, and laid stress on the sudden and suspicious leap from this crude performance, to the comparatively finished form, in which a striking similarity to Edisonian methods is apparent. He discredits the possibility of this lamp having been constructed in 1872, as claimed by the defendants, and enlarges on the suspicious suppression of these claims up to date, despite the many public opportunities afforded. Neither were the superior attributes of the improved Goebel lamp brought forward on other occasions, for instance, when Mr. Dreyer, in the process of organizing a

company, procured an option from Goebel, covering all the latter's inventions in regard to electric lighting. For this option the sum of $925 was paid, and it surely stands to reason that if Goebel was at this time in real possession of a lamp invalidating Edison's claims, his suppression of its existence could only be explained by a most remarkable indifference to his own commercial interests. This extraordinary silence was again manifested in later negotiations, and was at total variance with his openly expressed pride in his incandescent achievements, and his very natural desire to realize substantially upon his inventions.

Justice Colt also dwelt on certain additional facts, calculated to weaken the Goebel position. In the suit against the United States Electric Light Company, instituted in 1885, and again in the Sawyer-Mann Company case of 1892, the Goebel claims entered into discussion, and were ably and carefully investigated, with the result of establishing their utter fallacy. The court saw no reason in the present instance to depart from the decision rendered, and was therefore prepared to grant the required injunction in favor of the Edison Electric Light Company. No combination, however, of "bell, book or candle" has been discovered, sufficiently potent to lay the restless ghost of legality. Even as we write, that indomitable spirit is to the fore, and the revival of the Goebel claims, and there is a prospect of fierce and protracted fighting for all parties involved.

(*To be continued.*)

MACHINERY HALL, WORLD'S COLUMBIAN EXPOSITION.

BOILERS AT THE WORLD'S FAIR.

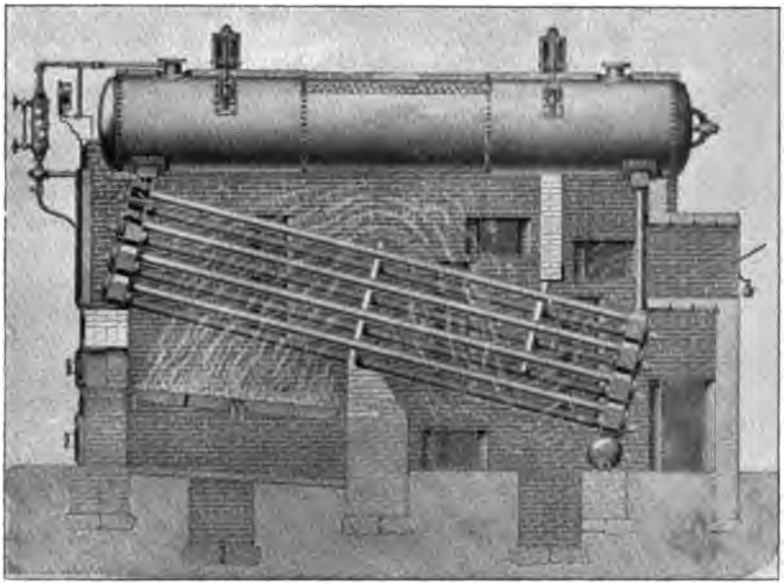
By H. W. York, Chief Eng. United Electric Light and Power Co.

Second Paper.

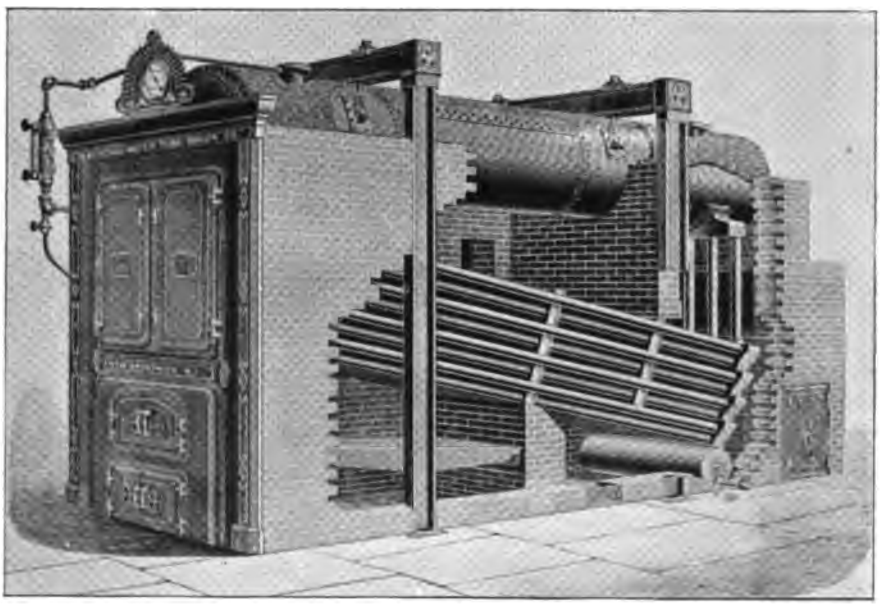
A FEATURE common to the four boilers remaining to be described, and forming part of the regular World's Fair boiler plant, is that they all have straight tube systems, like the Root and the Babcock & Wilcox boilers already mentioned in the first paper, the tubes being more or less inclined, and connected at the front and rear by headers or water spaces communicating with superimposed drums which contain either water alone or both water and steam. In this respect, therefore, there is some similarity between them, though in several other points they are quite unlike one another as will be seen at once by even a hasty glance at the several illustrations. The Heine boiler, for example, is distinctly different from the others in that it has a species of water leg at each end, instead of a system of headers in the generally accepted sense of that term, and its internal construction also presents several important features which are not found in any of the other designs. The Zell boiler, on the other hand, has a system of superheating tubes which is peculiarly its own and for which important advantages are claimed. The National and the Gill boilers bear perhaps the closest superficial resemblance to each other of the four designs shown in this number.

Of the National boilers there are shown at the exhibition four in all, set in two batteries, and rated by the makers at 1328 horse-power. The tubes are expanded into headers, whose construction will be readily understood from the appended detail view showing the front end of an overhead steam and water drum with header connection. The headers have openings opposite

FRONT END OF DRUM WITH HEADER CONNECTION OF THE NATIONAL BOILER.



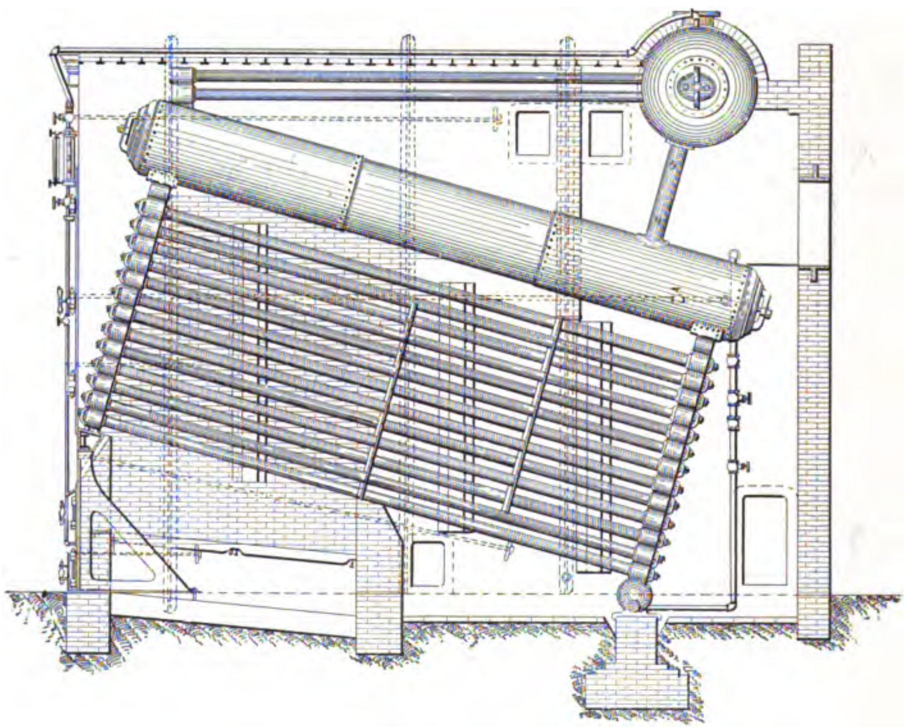
SIDE ELEVATION OF THE NATIONAL BOILER.



THE NATIONAL BOILER, MADE BY THE NATIONAL WATER TUBE BOILER CO., NEW BRUNSWICK, N. J.

the ends of the tubes, exposing the interior of the tubes to view and enabling them to be easily examined and cleaned. Any or all of the tubes in a section may be removed, if desired, through these openings, without disturbing the header and new ones replaced in the same manner. Should it become necessary, any header may also be removed without disturbing the others or removing any part of the walls of the boiler. The openings in the headers are covered with heavy plates, secured by suitable bolts. The sections are placed above one another in rows, side by side, and in this way the height and width of a boiler can be varied to suit varying requirements. Each header is connected to the one immediately above it, as well as to the one below it, by a short piece of boiler tube, expanded into bored holes, and by this arrangement the vertical rows of headers have a certain amount of elasticity, which allows for the unequal expansion and contraction between the bottom and the top rows of tubes.

In erecting these boilers, the steam and water drum is suspended from iron beams by means of heavy adjusting bolts and links connected to four plates attached to the drum at some distance from each end, thus preventing any tendency to sag. The beams themselves are supported by four iron columns, so that the brickwork and boiler proper are entirely independent of each other.

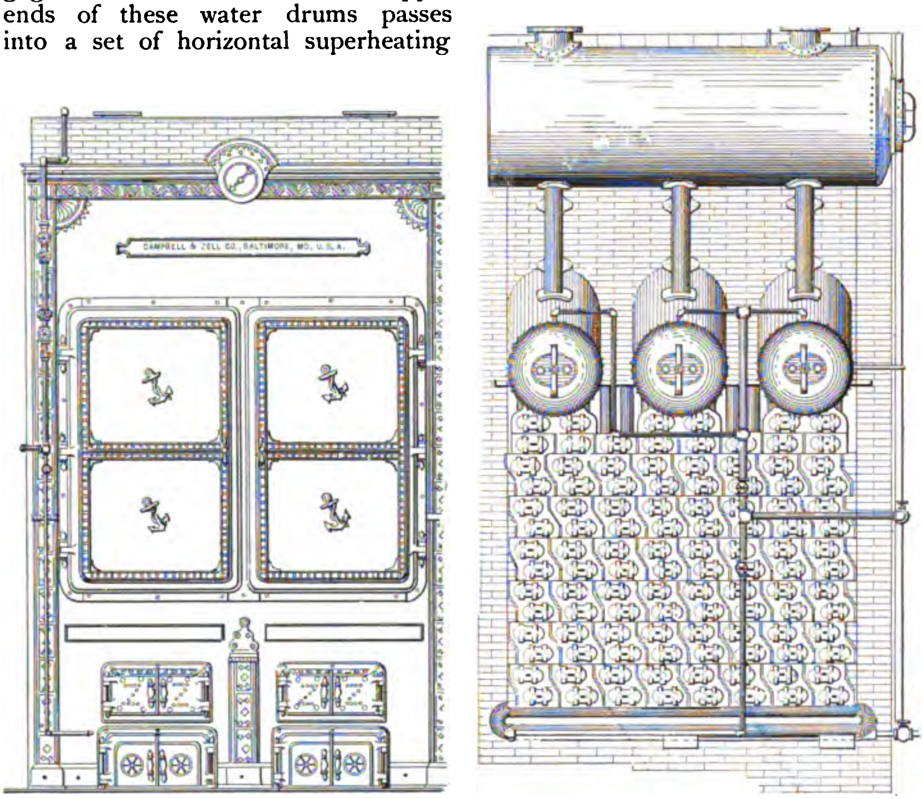


SIDE ELEVATION AND SECTION OF THE ZELL BOILER.

Differing somewhat in general design from the Root, Babcock & Wilcox, and the National boilers, though retaining the familiar inclined tube system common to these, are the Zell boilers, of which, in all, nine are on exhibition at Chicago, having an aggregate horse-power of 2850. The immediately strik-

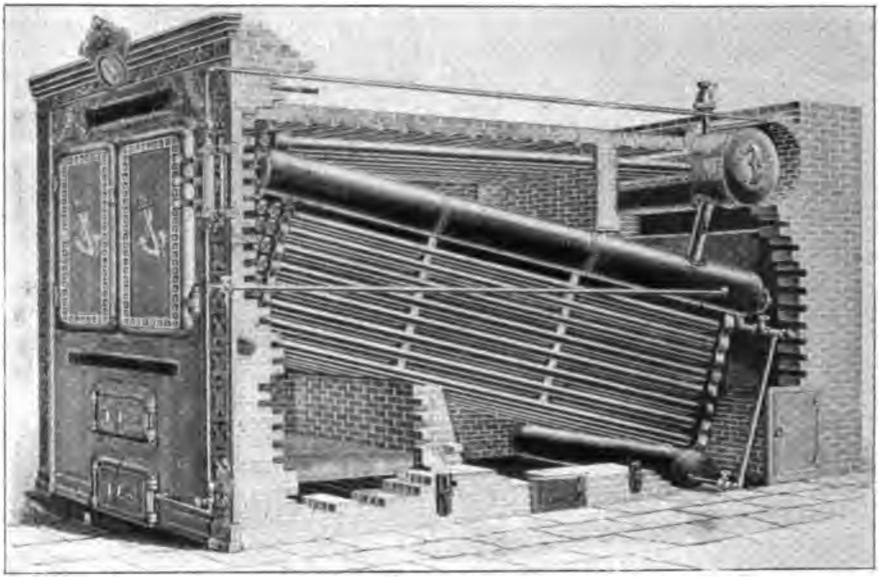
ing difference between these boilers and those mentioned is that there are no horizontal, longitudinally disposed steam or water drums, the drums used running lengthwise, being placed parallel to the incline of the tube system proper, and the water line being just below the upper part of their front ends. The steam disengaged from the water at the upper ends of these water drums passes into a set of horizontal superheating which points it naturally descends into the rear headers to be distributed among the tubes, and the greater portion of the impurities of the water precipitated by the heat will collect in the mud drum below.

The headers used in these boilers each accommodate four tubes, and are placed above one another and connected



FRONT AND END ELEVATIONS OF THE ZELL BOILER.

tubes, and finally into a transverse steam drum, which is supported by a water-tube at each end and connecting with the inclined water drums, but well out of the path of the hot gases. The drum is exposed to the hot gases for about three-fifths of its own circumference, thus providing additional superheating surface and insuring, it is claimed, perfectly dry steam. The feed water is introduced at the rear ends of the inclined water drums, from by short lengths of four-inch boiler tube expanded into holes in their tops and bottoms, thus forming continuous steam and water passages. The caps or plates opposite the tube openings in the headers are placed inside and are secured by T headed bolts that fit into pockets on the faces of the plates. It will thus be seen that the steam pressure in the boiler tends to hold the cover-plates against their seats, so that the greater the pressure the greater will

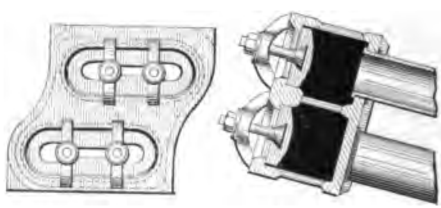


THE ZELL WATER TUBE BOILER, MADE BY THE CAMPBELL & ZELL CO., BALTIMORE, MD.

be the assurance of tight joints. Each header has two plates, and each plate covers two tubes. The sections proper, made up of headers and tubes, are placed in vertical rows and connected together by expanded nipples, the top row only being connected at their sides. From the top row of sections a short piece of tube is used to connect the water drums. The superheating tubes already referred to start from a row of headers placed across the tops of the front ends of these water drums, and are expanded at their rear ends into the transverse steam drum also previously mentioned.

Another feature peculiar to the Zell boiler is found in the method of setting, the boiler not being suspended from overhead beams and columns, but resting on two saddles placed under the mud drum at the rear lower end and on a roller carried by an arch plate over the fire doors at the front end.

One of the latest designs of the water-tube class is found in the Gill boilers, two batteries of which, each made up of six boilers, are on exhibition. In this boiler there is the usual inclined tube system and overhead horizontal steam and water drum, the tubes being four inches in diameter and spaced about three inches apart. Each nest of four or five tubes is expanded into a cast-iron box or header at each end in such a way that the tubes are staggered instead of being placed one above the



THE ZELL RHOMBOID HEADER.

other. By making these boxes short, and by connecting them by slightly flexible tubes, the danger of breakage from unequal expansion and contraction is avoided. The connection between the headers and the steam and water drum overhead is exceedingly simple, consisting of short tubes which

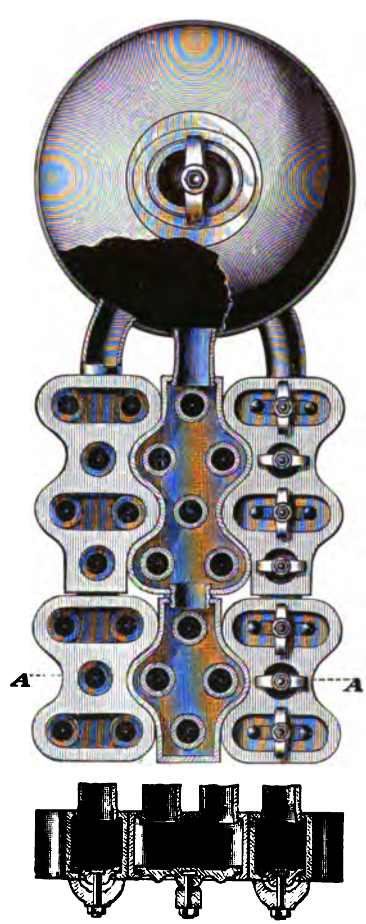
are expanded into the top of the headers and into the drum entering the latter radially, for which purpose they are curved to the proper form. The accompanying detail views more clearly explain the nature of the header and drum connections, the left-hand half of the larger illustration showing five and six tube headers with the caps removed, while in the right-hand half the caps are in place. The middle column shows a four and a six-hole header in section, illustrating the manner in which the headers are connected with one another and with the steam and water drum. The smaller illustration shows a pair of five-tube headers with the tubes and hand-hole caps in place. Under the rear row of headers is a mud drum connected to the bottom headers by short nipples.

The hand-hole caps are packed with thin rubber gaskets and are held in place by one-inch bolts. The caps, it will be noticed, are placed inside of the headers, so that the outward pressure of the steam helps to make a tight joint. The large overhead drums vary in diameter from thirty to fifty inches, and are proportioned to afford a cubic foot capacity for steam space and a cubic foot for water storage for each horse-power.

In erecting the boiler a structural frame work, composed of wrought-

FIVE-TUBE GILL BOILER SECTION

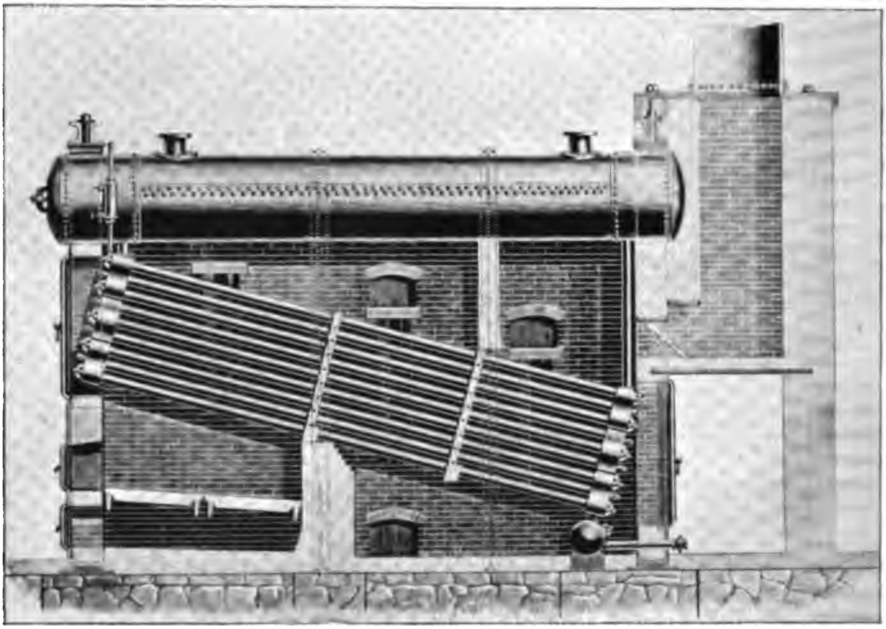
iron I beam columns and channel bar cross beams, firmly united with brackets, bolts and rods is put up, within which the drum, tubes and headers are suspended. The drums are supported in swings that are not attached to the drums, thus allowing the working parts to expand and con-



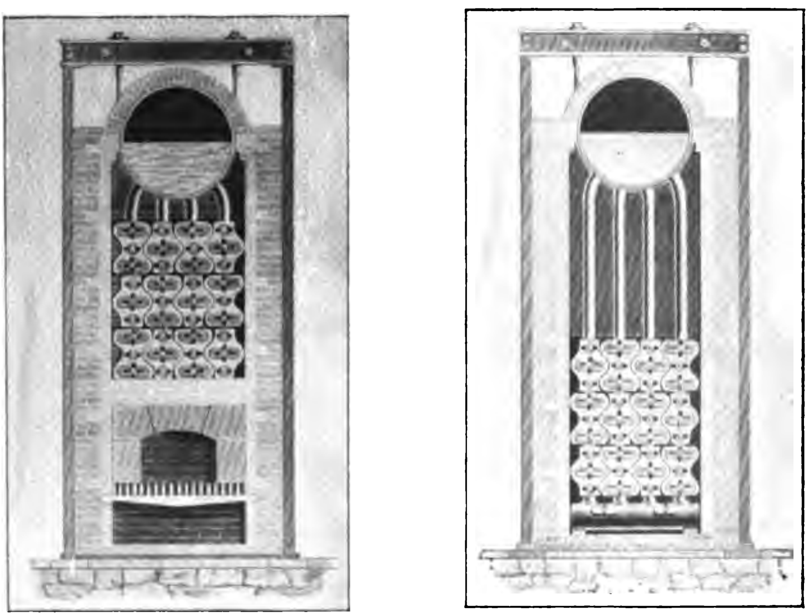
A BANK OF GILL BOILER HEADERS CONNECTED WITH STEAM AND WATER DRUM.

tract independently of the structural parts. All the iron work is made complete before the brick work is commenced.

In the case of the Gill boilers at the Fair, the contract called for a maximum continuous working evaporation of 45,000 pounds of water per hour from feed water at 212 degrees Fahrenheit into steam of 125 pounds gauge pressure, or the equivalent within the limit of pressure mentioned. During a



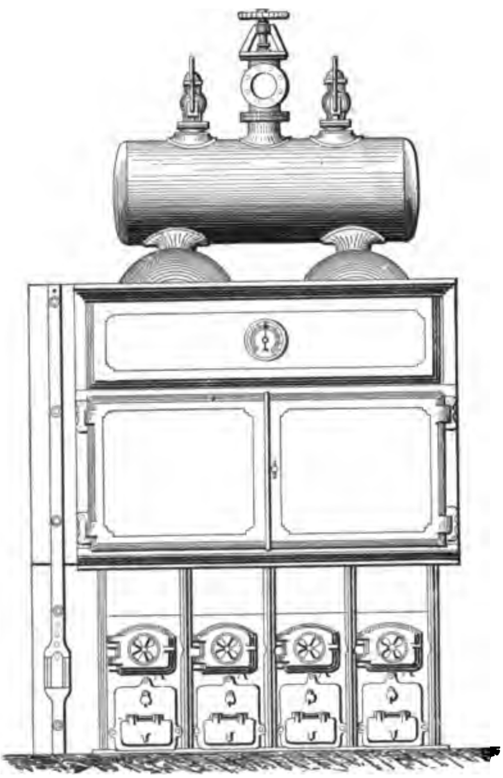
SIDE ELEVATION OF THE GILL BOILER, MADE BY THE STEARNS MFG. CO., ERIE, PA.



FRONT AND END ELEVATIONS AND SECTIONS OF THE GILL BOILER.

recent extempore trial the boilers evaporated 55,800 pounds of water per hour under these conditions, being about twenty-four per cent. above the contract requirement just stated.

The Heine boiler, the last to be described of the series furnishing steam for power purposes at the Fair, is in use not only in the main plant, where there are eight of these generators, but



FRONT ELEVATION OF THE HEINE BOILER.

also in the boiler-house annex in the Barre sliding railway plant, and in the Ferris wheel plant, these last three containing together, eleven. Each of the boilers is rated at 375 horse-power, and has two shells forty-two inches in diameter and nineteen feet three inches long, the shells being connected by a steam drum thirty inches in diameter and eight feet long. There are in such boiler also 171 tubes, three and one-half inches in diameter and sixteen feet long.

Both the tubes and the large longitudinal shells in these boilers have the same degree of inclination, the tubes connecting the inside faces of two water legs which form the end connections between them and the shells. These water-legs, so-called, are of approximately rectangular shape, drawn in at top to fit the curvature of the shells, and each is composed of a head plate and a tube sheet, flanged all around and joined at bottom and sides by a butt strap of the same material, strongly riveted to both. The water legs are further stayed by hollow stay bolts of hydraulic tubing, of large diameter, so placed that two stays support each tube and hand hole, and are subjected to only very slight strain. Being made of heavy metal, they form the strongest parts of the boiler and its natural supports. The water legs are joined to the shell by flanged and riveted joints, and the drum is cut away at these two points to make connection with the inside of the water legs, the opening thus made being strengthened by bridges and special stays.

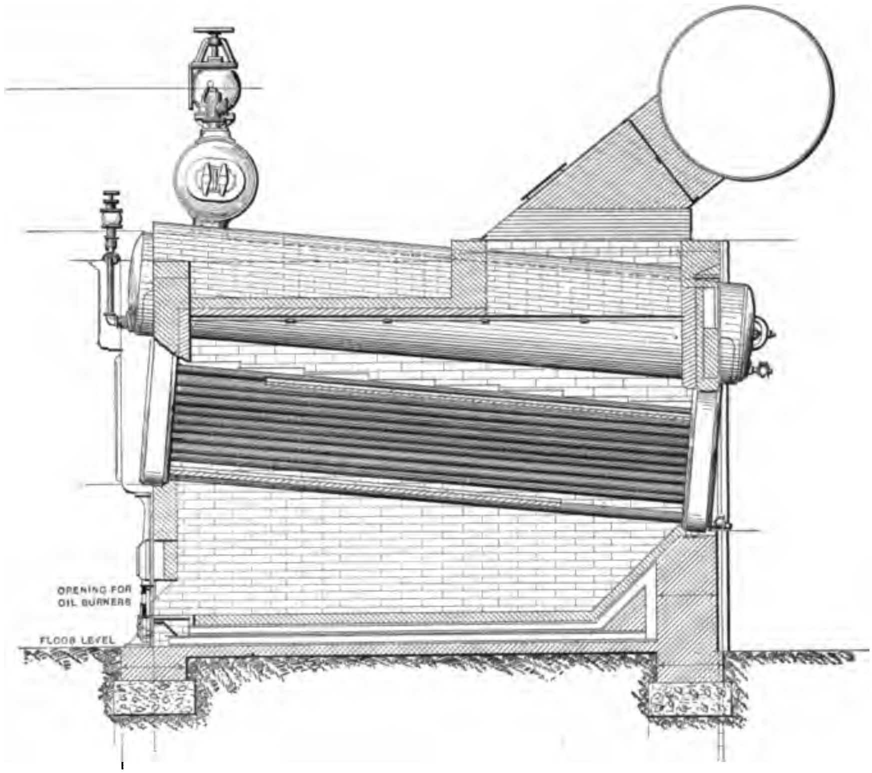
The shells are cylinders with heads dished to form parts of a true sphere, thus requiring no stays. To the bottoms of the front heads flanges are riveted, into which the feed pipes are screwed. The rear heads carry blow-off flanges of about same size as the feed flanges. On each side of the shells a square bar, a tile bar, rests loosely in flat hooks riveted to the shell. This bar supports the side tiles, whose other ends rest on the side walls, thus closing in the furnace or flue on top. The top of the tile bar is two inches below low water line. The bars rise from front to rear at the rate of one inch in twelve. When the boiler is set they are exactly level, the whole boiler being then on an incline, with a fall of one inch in twelve from front to rear. This makes the height of the steam space in front about two-thirds the diameter of the shell, while at the rear the water occupies two-thirds of the shell, the whole contents of the drum being

THE HEINE BOILER, MADE BY THE HEINE SAFETY BOILER CO., ST. LOUIS, MO.

equally divided between steam and water.

Opposite the end of each tube and in the head plates is placed a hand hole of slightly larger diameter than the tube and through which it can be withdrawn. These hand holes are closed by small cast-iron hand hole plates in the manner shown in the detail view, enabling their easy removal in case of need.

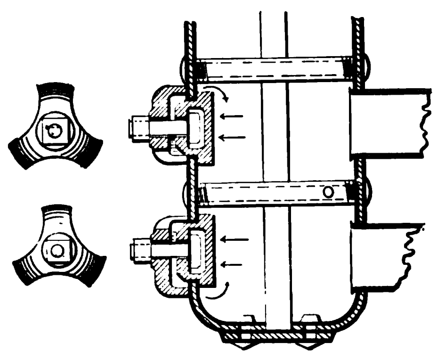
One of the peculiar features of the Heine boilers is found in the location of the mud drums. These are placed inside of the longitudinal steam and water shells, well below the water line and parallel to and about three inches above the bottom of the shells. They are oval in section, have cast-iron heads, and are entirely enclosed except about eighteen inches of the upper portions at the forward ends which cut away nearly parallel with the water line. The feed water enters the mud drums at a point about half an inch above the bottom, and, owing to its greater density than the hot water already in the boiler, remain at the bottom of the drums and passes to their rear ends. As it is gradually heated to near boiler temperature it rises and flows slowly in the reverse direction to the open front of the mud drums, where it passes over in a thin sheet, and is immediately swept backward into the main body of water by the swift circulation, thus becoming thoroughly mixed with it before it reaches the tubes. During this process the mud, lime salts and other precipitates are deposited as a semi-fluid "sludge" near the rear ends of the mud drums whence it may be blown off. As the speed in the mud drum is



SIDE ELEVATION AND SECTION OF THE HEINE BOILER

claimed to be only about one-fiftieth of that in the feed water pipe, plenty of time is given for this action. It may be added here that just under the steam nozzles in these boilers there are dry pipes and deflection plates, tending to prevent the carrying over of any water with the steam. Dryness of the steam is also insured by the fact that the height of the steam space in the front ends of the overhead drums or shells, owing to their inclined position, keeps the steam nozzles well out of reach of any spray. Whatever of this, however, there may still be, is caught and deflected.

In cleaning the boilers it is necessary to remove only every fourth or fifth hand hole plate in the front water leg; the water hose, supplied with a short nozzle, can then be entered in all the adjacent tubes, owing to the ample dimensions of the water leg. In the rear water leg only one or two hand holes in the lower row need be opened to let the water and debris escape. To keep the outside of the tubes clear of

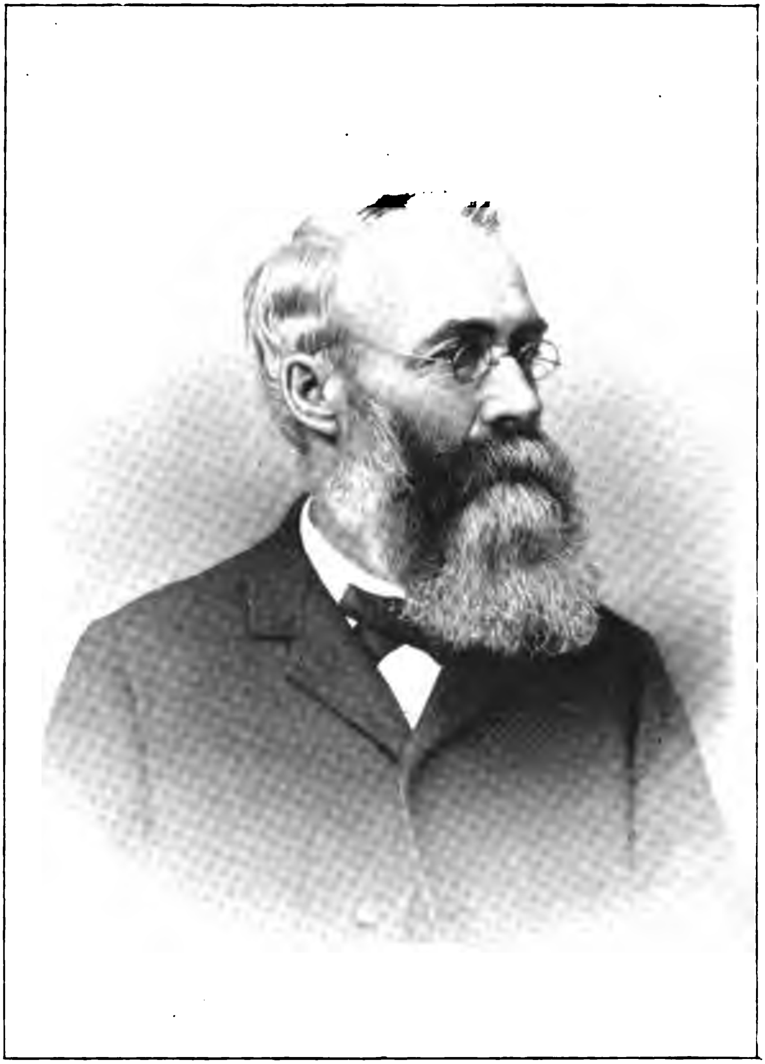


HEADER DETAILS OF THE HEINE BOILER.

soot and ashes each boiler is provided with two special nozzles with both side and front outlets, a short one for the rear, a long one for the front. They

are of three-eighth inch gas pipe, and each is supplied with steam by a one-half inch steam hose. The nozzle is passed through each stay bolt in turn, and thus delivers its side jets on the three or four tubes adjacent, with the full force of the steam at short range, knocking the soot and ashes off completely, while the end jet carries them into the main draught current to lodge at points in the breeching or chimney base convenient for their ultimate removal.

Before concluding, it may be well to explain that the boilers which have been here described are not the only ones to be seen at the World's Fair; they are simply those which are represented in the main boiler-house and in the boiler-house annex furnishing steam for the regular demands of the Exposition proper, a few of them also being located, as intimated in the course of the descriptions, at several additional points in the Fair grounds. As a matter of fact, several other types of boilers are shown, but they do not form part of the regular Exhibition power plant and have therefore not been included in this series.



E. D. Leavitt

CASSIER'S MAGAZINE.

VOL. IV. OCTOBER, 1893. NO. 24.

THE MANUFACTURE OF BRICKS.

By C. H. Schumann, C. E.

THE art of making bricks is almost as old as the history of civilization, the most ancient records bearing mention of the industry, showing it to be older than any other branch of pottery. It appears that the early inhabitants of Babylon, descendants of the sons of Noah, were the first clayworkers of whom we have authentic knowledge, for in 2247 B. C. (Genesis xi. 3. 4.) they used the clay or mud which was found on the plain of the land of Shinar and formed bricks therefrom, which were thoroughly burned and then used in the exterior construction of the walls and mounds of Babylon, the largest of these mounds, it is supposed, being the tower of Babel. The mortar or slime used as a binding material for the bricks was probably the semi-fluid bitumen found in the stoneless valleys of the Euphrates and Tigris. The interior of the mounds was filled with unburnt or sun-dried bricks partly laid in clay and bonded, every five or six courses, with layers of reeds and partly laid in very tough lime mortar.

Many ancient Egyptian buildings and pyramids, made in a similar manner of sun-dried bricks or adobes, are still standing in a good state of preservation, the pyramid of Howara, ten leagues from Cairo, being a notable example. The manufacture of brick seems to have been an important industry with the Egyptians and the enslaved Israelites, for it is frequently mentioned in the Old Testament, in connection with their history, one of the principal occupations of the slaves being the making of sun-dried bricks in which grass or straw and stubble were intimately mixed with the clay to bind the mass firmly together. The bricks made in Nineveh were usually sun-dried, measuring from six to sixteen inches square and from two to seven inches thick, while the Babylonian bricks were more frequently burned in a kiln and were about thirteen inches square by three inches thick. In addition to these, there were triangular bricks for corners of walls, and wedge-shaped bricks for arches. They were also variously colored, mostly red, yellow or blue, though green, black and white bricks were not uncommon. Many, notably all those made during the reign of Nebuchadnezzar, had his name stamped thereon. Evidences of the permanency of color of these bricks and of the inscriptions on some are constantly being found in the ruins of Babylon. Many that have been gathered are coated with a thick enamel or glaze. The dry, warm atmosphere and the preserving climate of Egypt, Assyria and Babylon have probably been more conducive to keep-

ing these sun-dried bricks in a state of preservation for over 3000 years than the great perfection attained in the making of them, although the ancients devoted an abundance of time to their arts.

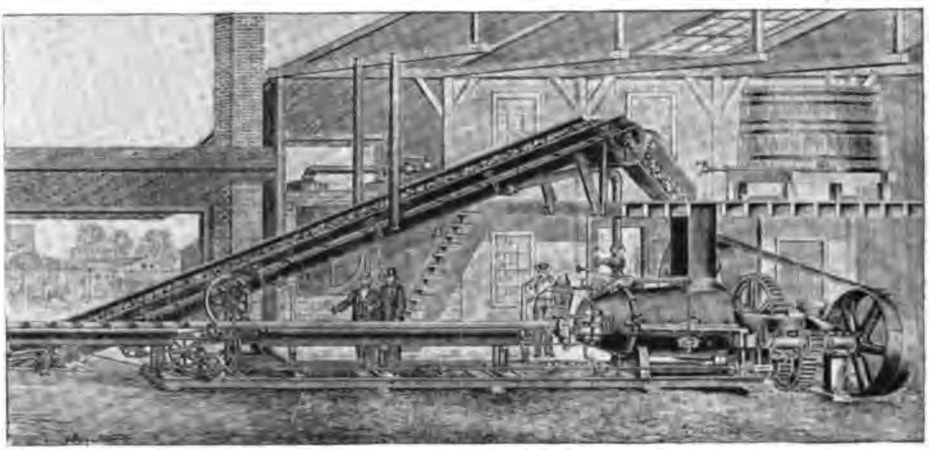
Sun-baked bricks of ancient date have been found in the mud walls of old towns of India and Java, while the Chinese have for ages made excellent bricks, usually of a slaty-blue color, to some of which they give a glazed surface, like porcelain. The great wall of China, built in 211 B. C., was constructed of burnt and unburnt bricks.

It is stated that the Greeks learned the art of brick-making from the Egyptians. They may have acquired it from the Assyrians in Cyprus. However, the Grecian bricks were generally of inferior quality, as most of the notable buildings and temples were constructed of stone of which there was an abundance in Greece. The walls of Athens seem to have been the only large undertaking in which bricks were employed by the Greeks, their use for construction seemingly never having been extensive.

The Romans made many public and private buildings of brick, often of excellent quality, and the credit of first burning bricks in kilns is generally attributed to the Romans, who certainly improved on the methods of brick-making practiced by the Greeks. The Romans perfectly understood the art, as the tiles in the bath of Titus and Caracalla bear witness. The Roman bricks, made early in the first century, were large, flat and thin, generally about two feet square and one inch thick. These gradually became shorter and thicker until, in the fourth century, they were about of the sizes used in modern structures.

The Romans appear to have introduced brick-making into England and Germany where the art was lost for a time. The earliest example of English brick construction is probably Little Wenham Hall, erected in 1260 A. D. Under Henry VIII and Elizabeth, the manufacture of bricks flourished, while in the fifteenth century it became common. The bricks were of excellent quality and of uniform size. During the reconstruction period, after the great fire in London in 1666, the buildings were generally made of brick, and architectural effects were produced by combining carved ornaments with the brick-work.

Examples of the durability and excellence of unburnt bricks are afforded by the adobe buildings of Peru, Mexico, New Mexico and Arizona.



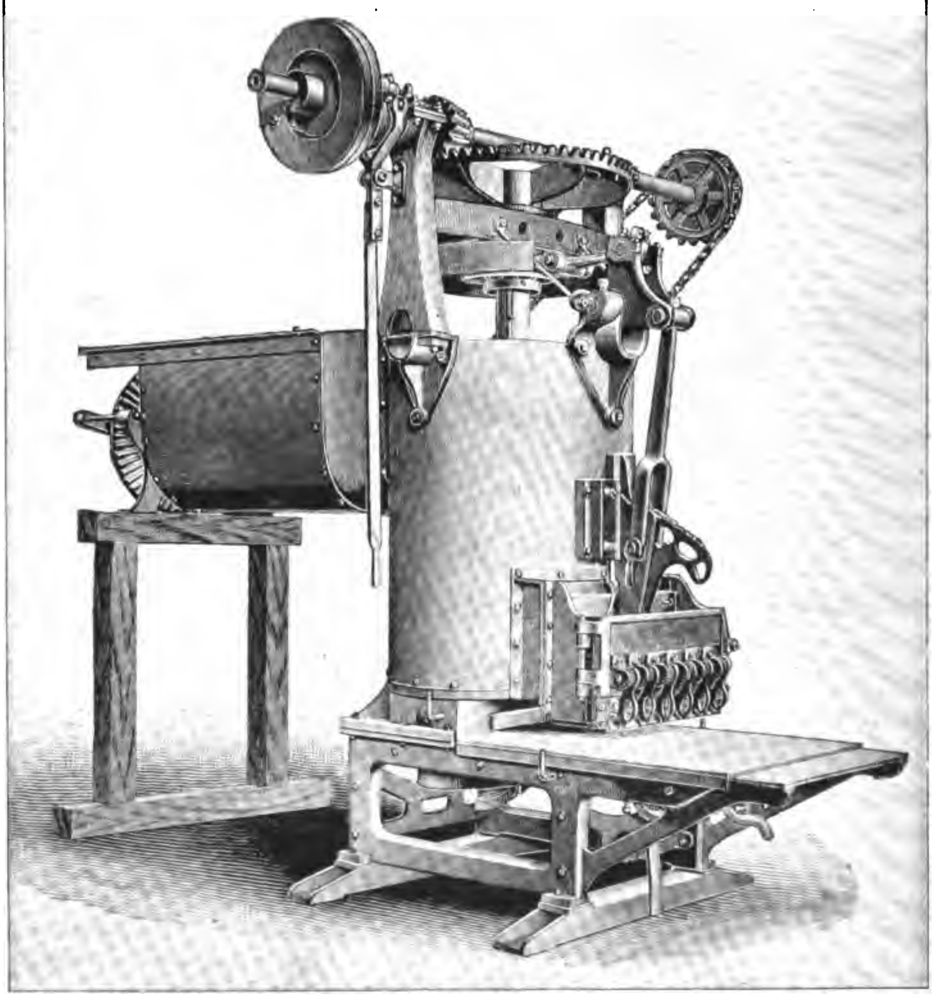
A STIFF-CLAY BRICK MACHINE.

A CLAY BANK ON THE HUDSON RIVER, N. Y.

Many of these structures were erected by the natives long before the advent of the white race ; some of these edifices have stood for more than three centuries with but the most trivial repairs.

The Dutch appear to have succeeded very well to the skill of the Romans. Their bricks have been famous from an early period for soundness and durability; so substantial were they, that specimens of Holland brick brought over to this country by the early settlers, are to be met with in some of the old Dutch houses in New York. The first brick building erected in this country was that for Governor Van Twiller on Manhattan Island, the bricks having been brought from Amsterdam. Probably the first bricks made in this country were burned at New Haven, Conn., in 1650.

A superior clay was found in Virginia by the colonists, but no endeavors at that time were made to use it for manufacturing bricks. Pennsylvania was not long in establishing primitive brick yards and erecting buildings of brick, for in 1685 there is mention of a dwelling being built of brick at Pennsburg. Massachusetts had its first brick edifice in 1700 in the "Triangular Warehouse" in Boston. Though brick-work was becoming common in the eighteenth century most of the bricks were imported from England. Immediately after the War of the Revolution, there was but little done in building and in brick-making, and the bricks that were made were irregularly molded and poorly burnt. There was little improvement on the primitive methods of making bricks by hand until about 1840. Prior to this, several brick machines had been invented and used, but no good results had been achieved. One machine, made like a plasterer's lime box, was slightly elevated, and the clay or mud mixed in it: this was allowed to pass through a grate into a large frame, divided by wires stretched both ways ; the frame was laid upon the bottom and when the clay in the box became somewhat hardened, the bricks were cut and formed by raising the wires. Bricks made thus were porous



A SOFT-MUD MACHINE WITH PUG MILL ATTACHED.

and full of cracks, there being no pressure brought upon the clay in the box, as is done by the brick-machines of to-day, or even by a blow by the hand-molder, who dashes the tempered clay into the mold with great force and presses it closer together with his hand and plane. Modern American brick-machines are of the most approved pattern and have contributed to the renown this country has obtained for the best quality and enormous production of bricks of every variety.

The earths most employed in brick-making are the hydrated silicates of alumina and are found in beds or pockets of different depths, distributed throughout the universe in great quantities. These clays have been formed principally by the decomposition and precipitation of feld-spar rocks. The brick-clays may be classified in first, the plastic clays, composed mostly of silica, and alumina in varying proportions ; second, the loams or sandy clays, and third, the marls, which are either sandy, clayey or calcareous, according as silica in the form of sand,

alumina or carbonate of lime preponderates in the mixture. These clays almost always contain a small percentage of oxide of iron, carbonate of lime, soda and carbonate of magnesia. Those containing a good proportion of oxide of iron form the red clays, which, when made into bricks, become more or less-red, according to the degrees of heat to which the bricks are subjected, and to the amount of iron present, which, however, should not exceed ten per cent. The red pressed brick of Philadelphia and other points obtains its deep color from these causes. silica and alumina which may come into actual contact with it. The quicklime, which will slake when the bricks become wet, destroys them. Magnesia present in the clays generally produces bricks of a brown color.

The presence of iron pyrites is objectionable, for the burning expels the sulphur, leaving oxide of iron or a basic sulphate, making the bricks porous and brittle. The purer clays contain one part alumina to two of silica, with a greatly varying percentage oı water in the different clays. They all, however, mix freely with water in differ-

DISMANTLING TEMPORARY BRICK KILNS.

When there is more than ten per cent. of iron oxide present the clay burns to a blue and almost to a black color. A large percentage of iron, with lime or an excess of silica present renders the clay fusible. Clays containing lime and very little iron burn white and need less intense heat to make hard brick than any other clays, the lime acting as a flux. Clays containing too much carbonate of lime are unfit for bricks; the lime, often present in the form of chalk, marl, or lime pebbles, is converted in burning, partly into quicklime, partly into a combination with the ent proportions, and become then tenacious and plastic. If molded and burnt they shrink, warp or crack. These rich or fat clays must therefore be mixed or "tempered" with sand, ashes or cinders before they can be used for bricks. Again, some clays contain too much sand, when they become weak and brittle after being burned; such clays may be mixed with the richer clays to obtain a product of good bricks. All brick-making clays should be free from pebbles, roots, vegetable remains, etc.

It results, therefore, from the great

difference in the nature and quality of clays found in various localities, that the methods pursued in brick-making must vary in different localities, the soft-"mud" method used on the banks of the Hudson River being somewhat different from the stiff-"mud" process elsewhere and wholly unlike the dry-clay method employed in the West and South.

One of the greatest "common" brick-making centres is the region along the Hudson River from Croton and Haverstraw northwardly on both sides of the stream. Here the clay is dug from "banks" close to the edge of the water, or is dredged from the river-bed, and deposited and stored on shore to be acted on by climatic influences until ready for use. It is well known that clays which have been exposed to the disintegrating action of frost and atmospheric changes for an extended period of time produce the best bricks.

Connecticut and northern New Jersey are large common brick-producing States, the clays found being similar to those of the Hudson River region, which often contain an undesirable quicksand.

Bricks of a cherry red color and of the finest quality are made in Pennsylvania, Maryland and the States bordering thereon, the loamy clays being of a superior grade. The clays found in the vicinity of Chicago are limy, producing poor building bricks, while the plastic clays around Milwaukee, containing a small percentage of iron, make light cream-colored bricks. Canada furnishes many good clay-producing localities. An infusorial, silicious and shelly clay is found in France and Germany, from which very light bricks are made, suitable for high-vaulted ceilings, or where lightness and safety against fire are desirable. It is known that bricks made of this material are so light that they will float upon water.

The best chemical analysis of clays will furnish only an approximation as to their brick-making qualities. The following table shows the varying composition of different clays:

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Silica	50.40	49.44	27.42	51.80	58.40
Aluminum	24.00	34.26	21.20	30.40	35.78
Oxide of Iron		7.74	8.60	4.14	3.02
Carbonate of Lime	2.70	1.48	2.16	....	....
Carbonate of Magnesia	1.30	5.14	3.98	0.30	2.72
Water, etc	21.60	1 94	36.64	13.11	
	100.00	100 00	100.00	99.75	99.92

Numbers one to three are suitable for common bricks and four and five are fire-brick clays. Number three is a clay taken out of the Hudson River at Croton, showing a high percentage of water absorption.

The process of making "common" brick from soft "mud" being most prevalent and adaptable in the Hudson River brick-making region, it is proposed to describe the various steps of this particular method and modifying the machinery and its application to the other processes.

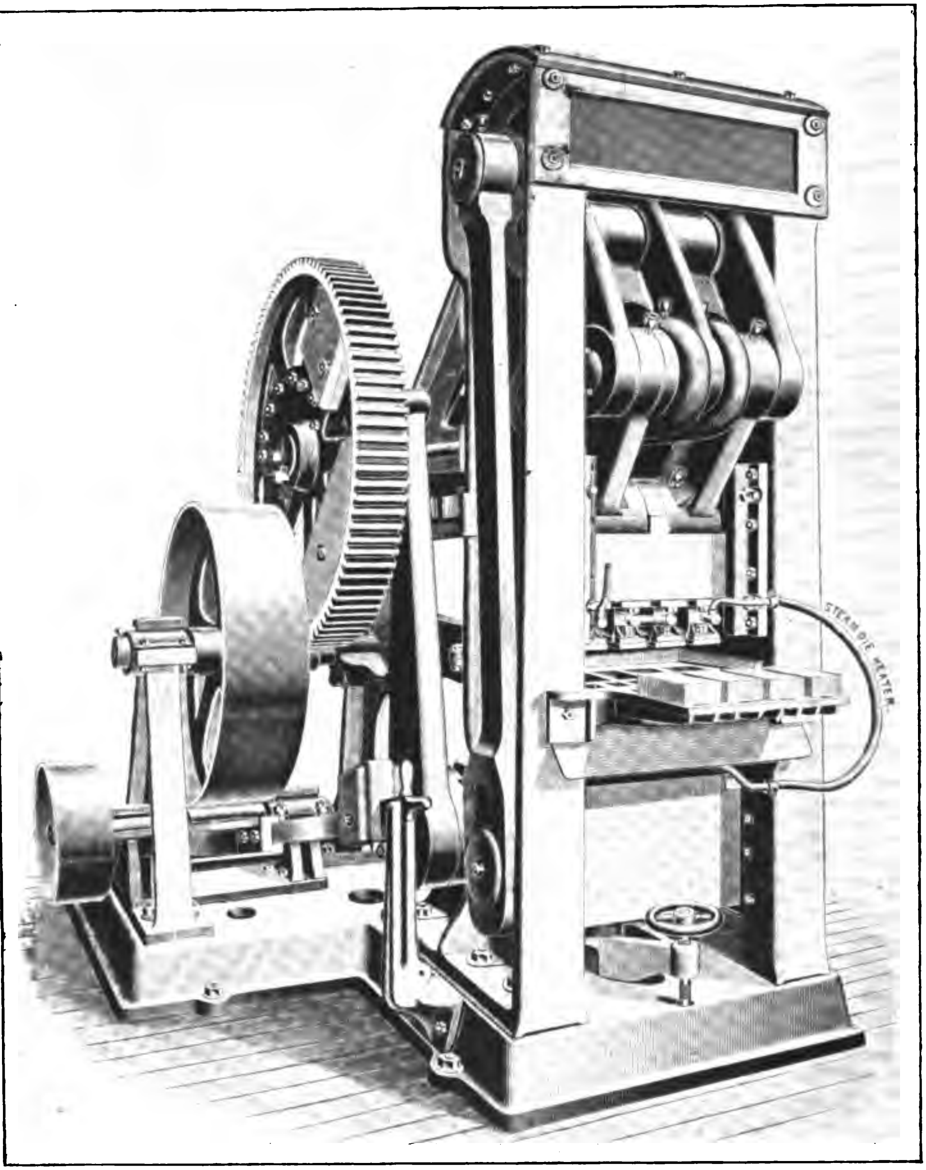
The entire operation may be classified under six divisions:

First, preparing the clay; second, tempering; third, molding; fourth, drying; fifth, setting the bricks in the kiln, and sixth, burning.

The brick-making period opening in March and April and lasting until the hard winter weather sets in, the clay-banks are found to be in suitable condition at the commencement of the season, the disintegrating influences of the previous winter having prepared the

A CLAY TEMPERING PIT.

clay for proper working. It is dug or undermined in "benches," laborers being generally employed to pick or shovel the clay. This as well as all brick-yard work being exceedingly laborious, it is found advisable to set the men to work at break of day, working them until late in the morning, thus avoiding the great heat of the summer afternoons. A day's work usually consists of the amount or quantity of product turned out. The clay is loaded into small dump-cars and hauled over a light-railed track by horse or steam power to the tempering pit, into which the clay is dumped. This pit or ring consists of a circular hole in the ground, is from twenty to thirty-three feet in diameter and from two to three feet in depth ; the wall or casing being formed of brick and the bottom of thick wedge-shaped oak or pine plank boards. Such pits are capable of holding clay sufficient to make from 20,000 to 40,000 bricks. In the centre of the pit is a vertical shaft which gears into a horizontal arm carrying the cutting or tempering wheel. This wheel is about six feet in diameter and has two narrow steel cutting tires bolted together. It travels by means of feed gearing, from the centre of the pit to the casing, back and forth on the horizontal arm, which also carries it around in the pit, ploughing and cutting through the tough lumpy clay mixture until this has been thoroughly "tempered" or reduced to a soft plastic "mud." This operation consumes usually the entire day. Before this tempering can take place, the clay, which is of the rich, fatty order, must be "seasoned." As stated before, sand, ashes or cinders are usually employed for this purpose, preferably sand. After the clay has been dumped into the pit, it is watered and allowed to soak over night. The next morning the mass is mixed with clean, sharp sand—in the proportion of one to two of clay—and to this is added fine coal-dust in the ratio of three pecks, more or less, to every 1000 brick batch of clay. The



A DRY-CLAY BRICK MACHINE.

practice of mixing this coal-dust with the "mud" has been often condemned as weakening the bricks made therefrom, but the results attained do not bear this out. The hardest common bricks manufactured are those made on the banks of the Hudson by this coal-dust method. Presumably the coal-dust, in the process of brick-burning, acts as a retainer of the heat, causing them to be thoroughly and uniformly "baked." Possibly it is a substitute for the straw which was put in the bricks by the ancient brick-makers. It is claimed for the coal-dust method, that it economizes in fuel and reduces the time of

burning the bricks. When steam power is used for driving the tempering wheels, several pits are placed in the same line of shafting and close together, the end of the horizontal shaft not extending much beyond the edge of the pit, which is not the case if horse-power is employed, the shaft being then necessarily extended and the pits further apart. To facilitate operations, one pit can be tempered while the neighboring pit is being shoveled out and the mud molded into bricks, which latter operation is the third step in the process of brick-making. The mud from the pit is generally wheeled in barrows to the brick-mold or press, which stands at a lower elevation than the tempering pit, the top of the press, which receives the tempered clay, being level with the wheeling floor, to facilitate charging from the barrows to the press. The soft-mud press, constructed of iron and steel, illustrated on page 406, is a common type of many machines of this class. It is about eight feet high and consists essentially of a tempering cylinder or tub of good capacity, being from forty to forty-five inches in diameter, and about fifty-three inches high, strongly bolted to a heavy cast-iron frame and a broad base. The whole is well built to withstand hard usage and the powerful motion of the mold-driver which is operated by a cam, geared into the main shaft. This main shaft is provided at its lower end with a heavy "S" shaped casting, called the wiper or pusher, which sweeps the tempered clay through a lateral opening in the front side of the press into a cast-iron box in which the rectangular piston-shaped mold-driver operates.

Where the clay is of such a nature that it can be used directly from the brick, the tempering is done in a pug-mill instead of in a circular pit, or less desirably, in the tempering cylinder of the brick-press, in which case the main or vertical shaft is provided with a number of steel knives which serve to mix the ingredients before being expelled by the wiper. The pug-mill is usually attached to the brick-press, as shown on the left of it, and consists of a wrought-iron shell from four and one-half to seven feet long and thirty inches in diameter, with a geared shaft running through it, provided with from fourteen to twenty steel knives of great power. The mill has a side feed into the brick-machine ; its capacity being small it must constantly be charged, and cannot, therefore, mix or temper the clay as uniformly as the circular pit does.

The bottom of the cast-iron box of the brick press has six openings corresponding to six brick-sized spaces in the brick-mold which rests directly under the cast-iron box and receives the clay pressed into it by the mold-driver. While one mold is being filled an empty one is inserted behind it, and upon the upward stroke of the mold-driver is forced forward in position to receive the next down-coming charge of clay, the filled mold thus being pushed out upon the receiving table. Superfluous clay in the mold is struck off by a tool called a "plane," resembling a plasterer's trowel. Each empty mold before being placed in position, is well sanded by the operator whose duty it is to insert the mold in the machine. The sand prevents the clay from sticking to the mold.

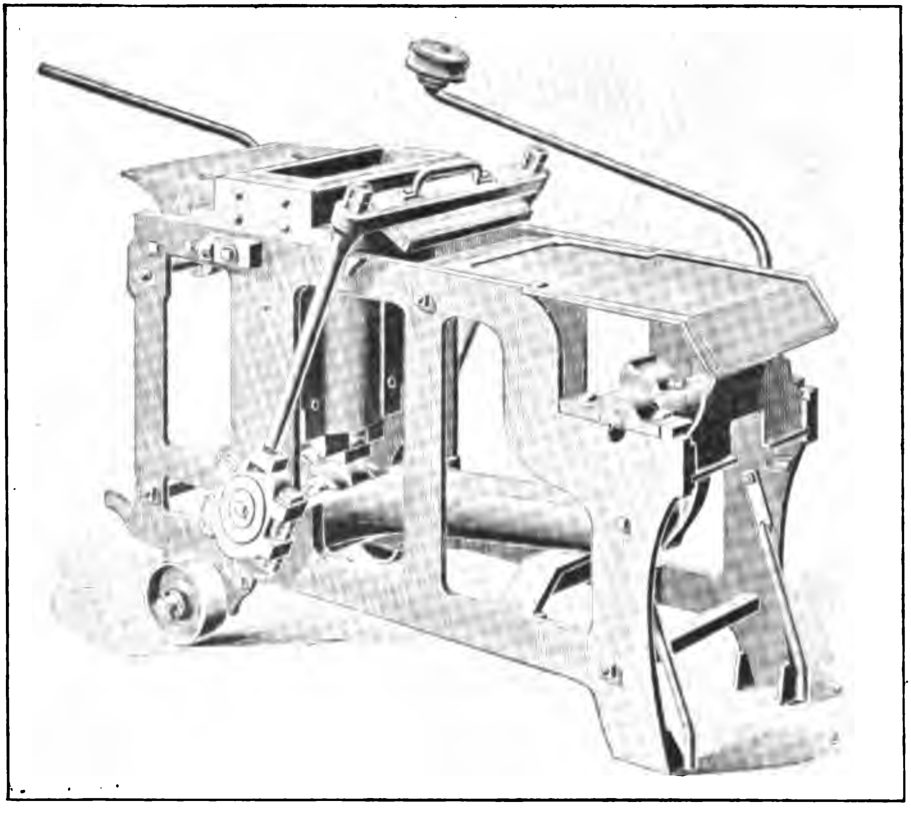
When the molds, which are made usually of cherry or locust wood, and contain six bricks each, are thrust from under the press upon the table, they are put on trucks and wheeled to the drying-yard, where the bricks, six in a row, are laid upon the flat. This operation is called "trucking off." The drying-yard is a large space with a smooth and level floor made of clay. The brick-press is always located at one end of this yard and housed under a rough, open shed. The drying-yard may be open or covered ; when covered, the roof is made movable, to be opened in dry weather and closed against rain and storm. There is no protection for the bricks drying in an open yard, though a freer circulation of air and light is obviously obtained. Bricks exposed to the rain are called "washed" bricks, and are not much esteemed.

The bricks, when partly dry, are "edged up," or set on edge, by means of an "edger," and are then "spatted" or tapped with a flat board called a "spatter" to give them a clean edge. When sufficiently dry, they are gathered by hand and placed on edge in long, narrow rows or "hacks" at the sides of the drying-yard. This process is called "hacking." The bricks remain in the hacks for several days, until thoroughly dry, when they are ready to be set in the kilns. Another mode of drying the bricks by hand is one known as the pallet system, in which the bricks are laid from the molds on long, narrow boards or pallets, each capable of holding conveniently a mold full of six bricks laid flat. These pallets are then placed in shelf-like tiers in covered frames, eleven shelves to a row, and two rows, containing 132 bricks, to a "pocket." The "pockets" are arranged end to end in long lines, with aisles for passage between all the lines. It is claimed that the bricks thus "hacked" dry faster than by the other method. They are "edged up" by hand to dry properly. Drying-ovens or patent dryers have not been an economical investment for the manufacturers of common brick in the Hudson River region, inasmuch as coal and fuel are not plentiful or cheap and the low market price obtained for this grade of brick does not warrant the outlay. Where space is limited and other conditions are favorable for the maintenance of drying ovens, it is of decided advantage to operate them, as by their use work can be continued throughout all seasons of the year. A form of direct-heat tunnel dryer is shown on page 416, and consists of six or more brick flues, about 40 feet long, 3½ feet wide at bottom and 2 feet at top, and 4 feet high; a slightly descending railtrack runs through each flue. Fire grates and doors are provided at the lower end, and a stack at the upper end of the dryer. Each flue has an iron door sliding in iron grooves, counterpoised by weights, thus allowing the cars, loaded with green or dried bricks, to be easily admitted or withdrawn. In addition to the gases from combustion, a large amount of air is admitted over the furnace into the flues. This air becomes heated and is then distributed over the bricks, after which it is carried off through the stack. Circulation of heated air may also be obtained by the use of steam pipes instead of furnaces, the oven then becoming known as a steam-dryer. Drying-ovens are impracticable for drying bricks made from very strong clays, or from those that will not dry without cracking in the sun. For loamy or sandy clays the dryers are acceptable.

The next step in the process of brickmaking is that of setting them in the kiln. Kilns may be permanent or temporary. Both are covered with rough, movable roofs. In the first, the kiln usually consists of two parallel high brick walls, or arches, permanently constructed. The green bricks ready to be burned are set or placed between these walls. At the base of each wall, running through and at right angles to it, are the furnaces, with their attendant grates and ash-pits. These are provided with iron doors, hinged to iron frames, which are securely attached to the kiln. Permanent kilns, when properly constructed, yield better results than may be obtained from the temporary kilns. The setting of the bricks in both is essentially the same. The construction of a temporary kiln is shown on page 407. In this the first bricks set are in the back arch. The arch is generally fourteen courses high, the bricks being set on edge and about one-half inch apart. The lower eight courses are usually called the "straight courses," on top of which are placed the "over-hangers," or remaining six projecting courses. The "pillar bricks" are those between the straight courses, and the skintles are the bricks set diagonally in order to tie together the over-hangers. The row first set on top of the arch is called the "tie-course," and the whole fourteen courses, the "lower bench," and the next fourteen courses, which usually complete the height of the kiln, are called the upper bench. A kiln is usu-

ally "forty-two high." The arch, lower and upper benches having been set, all on edge, a brick called the "raw platting," is laid flat on the uppermost brick course of the setting; on top of this a burnt brick, or the "burnt platting," is then laid reversed across it. The bricks having been set, the face of the raw bricks is then covered or "faced up" with boards set on end.

In burning the kilns, coal or wood may be used, although in the employment of coal fuel the arches of the temporary kiln must be provided with ash pits and fire grates. Before placing the bricks in the kiln, logs or, where obtainable, discarded railroad ties are placed at the bottom of the setting. These on becoming ignited in the process of the initial firing, serve to dry out



A HAND-POWER BRICK PRESS.

The opening through which the bricks are wheeled into the kiln and hauled out after burning is now closed or walled up with two thicknesses of bricks, each being plastered over with soft clay. All other sides of the kiln are plastered over to hold the heat when the kiln is on fire. A kiln as described usually holds about 20,000 bricks, and several such may be set at one working.

any moisture or dampness in the bottom of the kiln or in the bricks. The fires in the arches being started from each side to the centre of the kiln, the burnt platting is stood upon end to facilitate the escape of the white, watery smoke which is emitted during the burning for several days. The fires are increased until about the fifth day, when the white "water smoke" changes into a

AN OPEN DRYING YARD.

bluish-black. The kiln is now "hot," and the fire is seen to come through the top. The bricks at this stage are ready to shrink or "settle;" the platting is put down and tightened, and the fires intensified. After the bricks have settled sufficiently, and the kiln has "burned off," all doors and apertures are plastered over. The kiln then remains closed for about five days, allowing its contents to cool slowly, after which the bricks are ready for the market.

Burnt common bricks are divided into three classes, arch, red and salmon or pale. All are found in the same burning, the salmon bricks being largest in size and greatest in weight, are of poor quality, bringing the lowest marketable price. There are other plans for burning bricks, many of the annular kilns being very effective. Others operated by hot air, gas and air, superheated steam, etc., require unusual skill to work them. The second method of manufacturing bricks is the stiff-mud process. The essential differences between this method and the foregoing lie in the tempering and brick machines. The clay is hauled directly from the bank to the tempering mill which prepares it for the brick machine. Clay that is very tough and full of stones is first passed through elevated rollers which disintegrate it and remove the large stones. If necessary, it may be further pulverized and reduced by means of smaller rollers, suspended below the first set. By means of an inclined bucket elevator, the granulated clay is carried to the hopper of the brick machine. Where the nature of the clay admits it is fed directly from the bank to the hopper of the brick machine, where it falls into the tempering case, where it is tempered stiff by a limited quantity of water, and when necessary by the addition of loam or sand. The

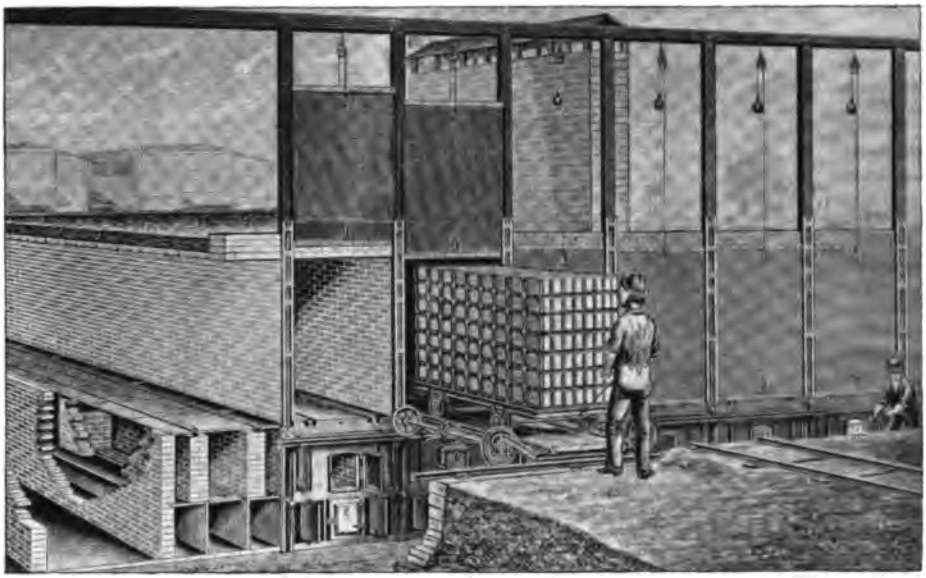
tempering case is conical in shape, and is fed at one side of the centre of the top, so that the clay, in falling, meets the revolving tempering knives as they come up. These thoroughly cut and force the stiff clay forward into the screw case, which contains, on the end of the tempering shaft, a conical screw of hard iron. In revolving, this forces the clay and delivers it into the "forming" die. The screw and die cases are heated by steam to facilitate the sliding of the clay. As the formed clay issues from the die it passes through a sand-chamber where it is evenly sanded, to prevent it from adhering or sticking. The formed clay, coming from the die in a long continuous bar, whose cross-section is of the standard or required size, is cut into proper lengths by means of a cut-off, which may consist either of wires on a revolving frame or of a revolving spiral blade of steel, the distance between each spiral (or wire) being equal to the length of a brick. The speed of either cut-off is controlled by the movement of the clay bar itself, thus securing uniformity in the lengths of the bricks.

In the dry-clay method of making bricks the clay from the bank is deposited under large sheds where it is allowed to dry. When fed to the charge-boxes in the press, it contains little or no sand, and very little moisture. An enormous pressure (something like forty tons) is then exerted to press this dry clay into brick form. The molded product thus produced has a uniform, dense and attractive appearance; upon being burnt, however, it is found that the bricks have become open and weak, and absorb water readily.

Many bricks, notably pressed or front bricks, are molded by the hand process, in which the molder takes a lump of the tempered clay as it comes from the tempering pit (generally worked by horse-power), throws a handful of sand over the lump of clay, works the mass into a peculiar shape or "warp," then dashes it down with great force into a cast-iron mold. Superfluous clay is struck off by the molder's "plane. This hand process of making common bricks is rarely seen except in very small communities, where the slow demand for bricks can be supplied by such method. The best pressed or front bricks are made by a combination of the hand and the machine processes. The clay should be well tempered; this is effected best in a circular pit; it is then molded by hand and the bricks placed to dry in the usual manner. When properly dried, the pressing-machine is taken to the bricks, which are carefully put into the press-mold one at a time. After the bricks are pressed, they are laid flat or in squares, edgewise, five or six high. When sufficiently dry, they are stored in sheds until required for burning. When set in the kilns, they are placed usually eight courses high, and in such a manner that the fronts may be preserved. All bricks are set one over the other, on edge, only the bottom, one middle and the top course being crossed. Great care is exercised in the setting and burning, the fires being lighter and more frequent than in the burning of common bricks.

Ornamental bricks and "shapes" are usually made in the same manner as pressed bricks, the molds in the press conforming to the different styles and designs. One of many pressed brick machines is illustrated on page 413. By raising the lever slightly, the head of the press is thrown from the mold. A green brick is then placed in the mold and the head restored. By lowering the lever, the head frame is depressed, holding the head firmly on top of the mold; simultaneously with the action of the head frame, a plunger advances from below, thereby pressing the brick. The lever is then elevated, forcing the plunger from the mold and liberating the brick. When pressed bricks are made from machine-molded fronts, the usual care exercised in the hand-process is not taken, and the product is not so uniform and desirable.

Fire-bricks are made from the most infusible clays, such as contain from fifty-two to eighty per cent. of silica, with from eighteen to thirty-five per



A DIRECT-HEAT TUNNEL DRYER.

cent. of alumina, and the remainder water. Oxide of iron may be present, but the light color of the bricks shows that this is in very small quantities. Such clays are of common occurrence in the bituminous coal measures of Pennsylvania, Ohio, Illinois and Missouri, where they are found in the underlying strata; they are also found associated with other clays of more recent formations, as at South Amboy, N. J., at Bennington, Vt., and Mt. Savage, Md. All these localities furnish the non-plastic fire-clay, which is particularly adapted to the manufacture of fire-brick, the plastic fire-clay being used for the production of pottery, terra cotta and an inferior grade of fire-brick.

The fire-clay, as found, is indurated and not generally refractory, and must therefore be broken up or ground, and mixed with some infusible material, such as pulverized quartz, finely ground old fire-bricks, clean silicious sand and gravel, powdered graphite, etc. The materials may be ground and mixed in a mill containing two roughly-surfaced rollers run at different speeds, or by a variety of pug-mills. The grinding and tempering are done very effectively by these means, after which the mass is molded into bricks either in hand-molds or by machinery, as described before; the bricks are dried, then set and burned, at a very high temperature, in kilns similar to common brick kilns, or more commonly in circular, domed, "over-draught," or annular kilns. It is for the lining of blast-furnaces and stoves that fire-bricks are extensively employed, and for this use they are prepared in a variety of sizes and shapes adapted to fit the curves in the lining of the stacks, the arches of the flues, etc. It is quite usual to find a fire-brick factory in the vicinity of a stove foundry, although the fire-clay is generally obtained from the great supply-banks of South Amboy and elsewhere. A common rectangular fire-brick is usually nine inches in length, four and one-half inches in breadth and two and one-half inches in depth, and weighs about seven pounds. Building bricks vary in size in different localities, the dimensions running from seven and one-half to nine and one-quarter inches long, three and one-half to four and one-half wide and two to two and one-quarter inches thick, the variation

being largely owing to the nature of the clay employed; weak clays in tempering absorb water slightly and shrink but little in burning, while the strong clays absorb large quantities of water and shrink very perceptibly.

English bricks are larger than the ordinary sizes made in this country, being about nine inches long, four and one-half wide and two and one-quarter thick. Machine-made bricks shrink less in drying, but more in burning than hand-made bricks. The average weight of a strong, well-burnt brick is about five pounds; it should be capable of withstanding a crushing pressure of about 7000 pounds to the square inch.

Bricks are enameled or glazed by means of a composition of porcelain or glass which renders the surfaces or faces vitreous. This may be done either by applying a flux or a chemical solution to the surfaces. Pigments of metallic oxides are added to the composition, which give it any desired color or shade. The composition with this pigment added is usually reduced to a homogeneous mass by pulverization, then it is calcined, pulverized again and made applicable by dissolving it in water to the consistency of cream. The faces of the bricks to be glazed are immersed in this solution or are coated with it by brushes, after which the brick is subjected to a temperature sufficient to fuse the enamel on the surface.

A process of making bricks entirely of sand and some vitreous composition has come to light in St. Joseph, Mich., which if successful bids well to revolutionize the entire brick-making industry as now carried on. The method consists in mixing sand with a chemical composition which effects a combination of all the sandy particles into a homogeneous and congealed mass, which is then molded by enormous pressure into any shape or design. Any color desired may be given to the mass. No drying or burning is necessary and it is claimed that the whole process can be operated on the most economical basis. The samples of bricks produced appear hard, smooth and dense and have clean and sharp edges and designs.

INTERCHANGEABILITY IN MECHANISM.

By W. F. Durfee.

IN an account of the development of the art of interchangeable construction in mechanism, presented at the recent International Engineering Congress at Chicago, the author endeavored to show that the idea of interchangeability in that field is of no recent origin, but that, in fact, if not in name, the commencement of its practical development was coeval with the satisfaction of the most primitive of the artificial demands of man upon the materials of the world in which he found himself placed. The subject is so vast, however, that it was impossible to treat it exhaustively in a single paper ; nothing short, in fact, of a copiously illustrated volume can convey an adequate understanding of the long, devious and weary way traversed by mankind in the journey toward the highest attainable perfection in handiwork, tools, machinery and their products. The most that could be given on that occasion were brief notices of the more important inventions which mark the various stages of the road along which improvement has journeyed, and a few extracts from these will well bear repetition in these pages.

In looking backward through the long perspective of the receding centuries for the first indication of an appreciation by man of the advantages of interchangeable construction, we recognize in the hands of the pioneers of the race, as they emerge from that "great deep" which, "without form and void," lies beyond the limits of authentic history, weapons and tools that possess the elements of interchangeability in as high a degree of development relative to the knowledge of the times as the most refined illustration of the art in our own day.

The bow of the primeval man had a sinewy string that would fit any other bow ; his arrows were adapted to any bow-string ; his paddle could be used in any canoe ; the head of his spear would fit any shaft, and his uncouth hammer of stone, from the great interchangeable manufactory of nature, would drive a tent-peg into the earth, or a skull into fragments.

There is nothing improbable in the supposition that all the primitive arts originated in man's necessities, and that a very general diffusion of a successful practice of those first essential processes was not only the explanation of their preservation, but was the creator of wants more or less artificial, to satisfy which other arts were devised, which in their turn led the way to more complex needs, one satisfied want creating an unsatisfied desire, which inventive genius gratified. Thus step by step through long ages past mankind has progressed. This slow engrafting of the artificial upon the natural man has been noticed by many ancient writers. Virgil says :

> "Jove willed that man by long experience taught
> Should various arts invent by gradual thought."

The term "interchangeable," as applied to mechanism, implies an ability to make a machine and all its component details exactly like a model, and it is obvious in the making of a multitude of examples of a specific machine, if the several details are made exactly like those of the model, that any one of these details can take its appropriate place, and perform perfectly its allotted functions in any one of

the machines. The more prevalent modern idea of the interchangeable in mechanism supposes a super-refinement of accuracy of outline and general proportions that is not always necessary or even desirable. It would be a criminal waste of time and substance to fit a harrow tooth with mathematical accuracy, but yet any harrow tooth should have a practical interchangeable relation to all harrows for which it is designed. The instructive rewards of folly would certainly overtake him who should attempt to make "plow shares" and "coulters" with radical exactness, nevertheless these essential parts of plows should be interchangeable among all plows to which they are adapted.

This allusion to the common practice of our time of making the parts of agricultural implements and mechanism roughly interchangeable naturally calls to mind the earliest method of making the metallic parts of implements and apparatus in like manner—the art of casting.

This art has come down to us from a period of which history is ignorant, and from a people whose footprints have been obliterated by the dust and debris of uncountable centuries. Whoever the discoverer of this art was, whether the Vulcan of mythology or Tubal Cain of the Scriptures, he is deserving of most honorable recognition; and if present civilization was disposed to be as just to its creators as that of ancient Greece, it would imitate its altars "to the unknown gods" by the erection of a monument of no mean proportion to the unknown inventors who, by their discoveries, laid broad and deep the foundations of the arts of our time. Without dilating upon what has been accomplished by the art of casting among ancient peoples, it may not be without interest to call attention to the evidence of the antiquity of castings of iron that has not hitherto received much attention.

It is well known that the heads of the battering machines used in ancient warfare were sometimes made of iron, and were shaped like the head of a ram. From this fact, and the suggestion of its movement when in action, these machines were called battering rams. The heads of these machines were exposed to a terribly destructive impact when in use, and therefore it is justifiable to suppose that they would have been made of a material easily shaped, and from which duplicate heads could readily be supplied. Forged iron does fulfill these conditions, being difficult to obtain in large masses at the time, and it is absurd to suppose that the ancients would have expended the time and labor necessary to carve a lump of wrought iron in the elaborate realistic way indicated by all the representations of battering rams shown on ancient monuments. As it is certain that these rams' heads were often made of iron, it appears to be more than probable that some tough variety of cast-iron was used, in which case a new head could readily take the place of a broken one, and the business of the siege go on without serious interruption.

Another evidence of the appreciation of the value of interchangeability of similar parts in ancient weapons of the heavier sort is found in the gearing for twisting the funicular springs of catapults. This gearing is described by Rollin as being made of cast brass or iron, but the Chevalier Folard states that it was made of cast-iron. The origin of the catapult is uncertain, but it is believed to have been used by Nebuchadnezzar at the siege of Jerusalem and Tyre (586, 588 B. C.). Thus early did military engineers perceive the advantages of interchangeability among the more important similar metallic parts of machines of war, and thus early does cast-iron appear as a material from which some of these parts were constructed.

Neglecting minor examples of the interchangeability of parts produced by the art of casting, we come to the making of movable types. This art is without doubt the most important exemplification of the grand results that have sprung from the original discovery that metals could be given any desired form by melting and pouring them into appropriate molds.

The printer's art rests firmly and solidly upon the art of casting, for the

experience and skill of man for the past 450 years has utterly failed to find a satisfactory substitute for the art of casting by which to produce with requisite economy and precision the interchangeable type whose invention marks distinctly the beginning of a new area in the life of man upon the earth. As soon as movable types were invented it became evident that extreme accuracy was essential in their production; in each variety of character in a font all types of the same letter must be alike both in face and body, and the bodies of all the type must be so related to each other, and to the "quads" and "spaces," that a given length of line can be perfectly filled. In the history of mechanical development nothing possible of attainment by ingenuity and handiwork has ever been asked of the artisans of the world that they did not immediately supply, so this demand for a precision of execution unheard of before was met by workmen whose skill was quite equal, if not superior, to any of our time.

Some recent careful examinations and measurements of repetitions of the same word in black letter volumes about four centuries old prove the correctness of the statement just made, for the agreement is quite as close as noted in modern publications. In estimating the skill of the original type founders, we must not fail to remember that they were destitute of all those tools which are considered essential by modern skilled workmen for the production of accurate work in metal. "Lathes" were crude and sporadic. The "planing machine" was 300 years in the future, and the "shaping machine" fifty years more remote. The "micrometer" was 180 years ahead of them. The "milling machine" was far below their horizon of time. The "black lead pencil" had not been invented, and the English unit of measurement was a "barley corn." Besides the art of casting, their dependence for the execution of good work (such as that required on the molds for type) was on hammers, chisels, files, gravers, scrapers, grinding, the bow-drill and burnishers; these were the tools which skillful hands and keen eyes used in those days in the working of metals.

While the originators and early practicers of the art of printing were successful in casting (the early printers were also type founders) types that would interchange among those of the same founder, the types made by different founders would not interchange with each other, and it is to the credit of American artisans that they have perfected a system of manufacture by which it is quite possible to "make up" a "form of type" as large as the side of an ordinary newspaper, and, notwithstanding the fact of the types having come from half a dozen foundries, there will not a type leave its place when the form is held horizontally by its "chase."

In recent years the art of casting type has been combined with the art of "composing" or assembling them into words and sentences. By means of exquisite mechanism, actuated by power and controlled by keys properly fingered by the compositor, certain letter matrices are arranged in exact order at the bottom of a mold. Whenever a sufficient number of such matrices are assembled to form a line of predetermined length, melted type metal is forced into the mold, and as soon as it solidifies the solid line of type (hence the name "Linotype," of the apparatus) is thrown out of the machine. This machine is a splendid example of the modern system of interchangeable construction, and for accuracy of workmanship and the perfect adaptation of means to ends, as well as for its rapidity of operation, it deserves to take rank among the wonders of human ingenuity.

The art of stereotyping is only an amplification of the art of casting single type, and to such perfection has the art attained in some of the larger newspaper offices that it is not unusual to make a papier-mache mold from the flat form of type, curve this mold to a proper radius, cast the stereotype from the mold, secure it to the cylinder of the fast press, and have the newsboys crying the *n*th edition of the Heraldic

Tribune and Cosmopolitan Sun within twenty minutes after the arrival of the "form" in the stereotype room of the printing office.

For the invention of the art of printing the world is indebted to Germany, and if that great nation,

> "Renowned for arts and arms, for manly talent and for female charms,"

had never made any other contribution to the commonwealth of knowledge, it would still be entitled to the grateful homage of mankind throughout the ages yet to be. So noble an art as that of printing deserves the best that thought of brain and skill of hand can give. It has made the possibility and potentiality of knowledge the common heritage of all lands and peoples, and constituted itself the integrator and conservator of the science of the whole world.

Nations may rise or fall, dynasties may perish; but so long as man dominates the earth, the art of printing will be the educator of the succeeding generations, and will hand down from father to son, even unto the end of time, the ever accumulating wisdom of the rolling years.

The "lathe" may safely be accounted the oldest of machine tools. Save that of the husbandmen, the tailor and the art of lying, there is no art older than that of "turning"; for we are told that Adam and Eve were "turned" out of Eden, and the first turning tool ever mentioned in history, is the flaming sword of the sentinel Cherubim, which "turned every way."

It is certain that the potter's wheel, doubtless the parent of all lathes, has been known from the earliest times. Potsherds are mentioned in the book of Job, and no ruins are so ancient that fragments of the work of the potter are not found therein. The transition from a rotation about a vertical axis, to revolution about a horizontal axis, and from shaping a soft mass of clay with the fingers for turning tools, to the shaping of wood with a tool of iron or steel, seems to us at this day to be very simple and easy; but, judging from the exceedingly slow progress of the development of the art of wood turning after its discovery, it is pretty safe to assume that several hundred years elapsed after the invention of the potter's wheel, before anything like the rudest form of the wood-working lathe became known.

Diodorus Siculus attributes its invention to a nephew of Daedalus, named Talus, about 1240 B.C., but Pliny states that it was first used by Theodore of Samos about 740 B.C., and mentions one Thericles, who rendered himself famous by his dexterity in using it. The ancients employed it for turning a large variety of forms of vases, some of which they enriched with carvings. Centuries afterward, mankind began to perceive that the idea buried in the rotating mud of the potter's wheel could be still further expanded and made useful for the shaping of metals, and at this point in its history the "lathe" begins to assume importance as a contributor to the art of interchangeable construction.

In 1578 Jacob Bessoni published at Lyons a remarkable folio containing sixty full page copper plate illustrations of a variety of instruments and machines, among which are three engravings of lathes. One of these contains a suggestion of a guide bar with a serpentine groove, and various holes designed to direct and assist in controlling the peculiar hand tool employed. This clumsy machine tool gives us a hint, somewhat feeble it is true, but still a reminder that there was a feeling among the mechanicians of that day, that some machinery for turning irregular forms was desired, and that they had begun to grope around in the outer darkness where everything was "without form" in the hope of discovering some means to satisfy that desire. Another of the plates in Bessoni's work furnishes the first published suggestion for a screw-cutting lathe provided with a "guide screw," and the beginning of a "slide rest," in means to solidly hold the cutting tool, while the screw being cut was moved longitudinally as it revolved in contact with it. The guide screw, and in fact the whole structure of this lathe, is a crystallization of the uncouth,

both in idea and in execution; but nevertheless it affords conclusive proof that there was a slowly developing demand for more exact work than had hitherto been possible, and that inventors were endeavoring to satisfy that demand.

The lathes described by Bessoni were all "dead centre" lathes, and the work did not have a continuous rotation, but was alternately revolved by a cord, in a manner similar to a bow drill. This feature seems to have been common to all lathes prior to Bessoni's time. It seems strange that the economy of time, and the other advantages of a continuous rotation, as exemplified in the "potter's wheel," were not regarded by the makers of the early lathes.

The royal license and protection granted to Bessoni, by Charles IX. of France for the publication of his inventions, was really a royal patent for all the machines described, and therefore Bessoni's book may properly be regarded as the drawings and specifications of this early patent, which if not the first, is certainly more comprehensive in its scope than any other ever granted to an inventor of machinery.

The license of the king is such a curiosity of brevity and emphasis, that it is quite justifiable to quote it entire :

THE LICENSE OF THE KING.

"By full and special license of the King given to Master Jacques Bessoni, author of this present work, for ten years in the near future, dating from the day when the work is finished by the printer ; all persons of whatever rank or condition they may be, are prohibited to make, counterfeit, engrave, sell or to consent thereto, even to the drawings for manufacturing, the inventions contained in the present work, without the permission of its author. Upon the penalties contained and specified by said license. Given at Orleans in the year one thousand, five hundred and sixty-nine, on the twenty-seventh day of June.

"By the King in Council,

"(Signed) Brullart."

Grinding machines for the production of flat and cylindrical surfaces by the action of emery or corundum wheels had their origin in America, and have largely augmented the possibility of cheaply producing accurate work in metal. The grinding lathe, as perfected by J. Morton Pool in 1868, is believed to have been the first apparatus by which long cylindrical rolls could be given automatically and at once an accurate surface and uniform diameter. So delicate is the action of the very simple mechanism employed that a uniform reduction of diameter of 1-20,000th of an inch is quite within its powers. The invention and successful operation of this admirable tool has made possible the manufacture of widths of paper unknown and unattainable before. The success and possibility even of the various grinding lathes and similar machine tools that have been developed in the past twenty years is due to a very simple American invention, the solid emery or corundrum wheel, which has ground its way into recognition and universal employment in all the machine shops of the world.

The modification of the lathe known as the boring machine probably originated in Germany ; for in a work published in Nuremberg, 1662, there is an engraving of a duplex boring mill, operating upon two musket barrels at the same time, and in a treatise on artillery, published in France in 1647, there is a vignette in which a cannon is shown as being bored by a vertical bar. About the middle of the last century, cannon and pump cylinders, also cylinders for Newcomen engines, were bored horizontally in rude boring mills at Carron Iron Works in Scotland, and in 1769, that celebrated engineer, John Smeaton, designed new boring machinery for these works. It does not appear that this machinery was perfectly satisfactory, as in a proposal from Boulton & Watt, to the Carron Iron Company, in 1776, for the construction of an engine to return the water to their water-wheels, Mr. Boulton says : "Mr. Wilkinson has bored us several cylinders almost without error ; that of fifty inches diameter, which we have put up at Tipton, does not err the thickness

of an old shilling in any part, so you must either improve your method of boring, or we must furnish the cylinder to you." "The thickness of an old shilling" seems to have been regarded as a very satisfactory standard of permissible error in such work one hundred years ago. The Mr. Wilkinson spoken of by Mr. Boulton was John Wilkinson, of Bersham, near Chester, who had invented improvements in boring machinery in 1775. He it was who first moved a cutter head along a boring bar, supported at each end, and as simple as this idea now seems, it was not perceived by such acute men as Smeaton and Boulton and Watt.

The first planing machine of which we have any account is said by Rennie (Buchanan on mill work) to have been invented by Nicholas Torq, a French clock maker, in 1751, and to have been actually used in planing the interior of the wrought iron pump barrels, used in the machine erected by order of Louis XIV., for the supply of the water-works at Versailles.

The art of wire drawing has been a liberal contributor to the development of the art of interchangeable construction. The making of wire was originally accomplished by beating the metal into thin strips, then shearing it into strands of a more or less square cross section, and then hammering these strands until their angles disappeared, and the strands became approximately round.

Until early in the fourteenth century, this had been the only method of making wire from remote antiquity, and was probably practiced in Egypt, in the time of Moses (1450 B.C.), for we are told in Exodus 39, 3: that "They did beat the gold into thin plates and cut it into wires, to work it in the blue, and in the purple, and in the scarlet, and in the fine linen, with cunning work."

This rude method was improved in Germany by the invention of the draw-plate, which was in use at Augsburg as early as 1350. So long as the rounding was accomplished by the hammer, the workmen were called "wire smiths"; but after the invention of drawing, they were named "wire drawers" or "wire millers." So slow did improvement travel in the middle ages, that "wire drawing" was not introduced into England until about 200 years after its invention in Germany.

The art of interchangeable construction was strongly reinforced by the discovery of the method of forging in dies. This idea was but an application of the art of coining cold metal for use as money (which had been known since the time of Darius, 500 years B.C.); to the shaping of metal while hot. The art of forging in dies is believed to have originated in France about the middle of the twelfth century; and numerous examples of "hinges," "grills" and wrought iron ornaments of various kinds remain as elegant testimonials of the cultivated taste and wonderful skill of these ancient artists in iron. Forged ornaments shaped by dies were common on all the pleasure carriages made in the last century, and it is certain that the wonderful "one-horse shay" would not have been the masterpiece it was if its "step-irons" had not been decorated with "swaged" ornaments.

It seems but a very short step indeed from the forging of ornamental iron work in dies to the forging of the smaller parts of machinery in the same way; but as short as it undoubtedly was, it does not appear that it was taken until the late Albert Eames introduced the practice of forging parts of muskets and pistols in "dies or swages" at Chicopee, Mass., in 1842.

One more step forward in the art of forging the parts of interchangeable mechanisms brings to us what is known as "drop forging." This art is believed to be of American origin, and was first used at Harper's Ferry, Md., in the year 1827, in the works of J. H. Hall. An improved form of drop forging machine was made by the late Albert Eames for the Remington Works at Ilion, N. Y., in 1846. From this date the use of the process of drop forging has rapidly increased, and it has been applied to the manufacture of very intricate as well as delicate articles. The Billings & Spencer Company of Hart-

ford have for the past twenty-five years turned out annually large numbers of shuttles for sewing machines so nearly exact in size as to require little work and polishing to render them fit for their intended service. The art of drop forging is also used for producing the heavier parts of bicycles and for an endless variety of forgings in iron, steel and copper, forging of the latter metal having come into use for electrical machinery within the last eight years. So important has the art of "drop forging" become as a factor in manufacturing that at the present time no establishment for the manufacture of interchangeable mechanism, of which forgings are a component part, can afford to ignore its advantages. In the making of drop forgings, the preparation of the dies is a matter of the first importance, and so high has American skill in this particular been appreciated abroad that from time to time large numbers of finished dies have been sent from America to foreign countries. The Billings & Spencer Company of Hartford, Conn., who are pioneers in the art of drop forging, shipped at one time forty-two tons of dies to Prussia for the makings of forgings for the parts of muskets.

Looking backward at the art of interchangeable construction as exemplified in the work done at the beginning of the century, and viewing it in the light of the exact requirements of to-day, it is certain that very little of the work done at that time would pass inspection now. Most of the parts of the old muskets would doubtless interchange, but the exactness of the relations of the parts would not be found up to present standards. The demand for such precision was not made, and could not with the means at command have been realized if it had been insisted upon. Even the mechanical means of attaining interchangeability in some of the parts of muskets were not invented until 1853.

Since that year American gun-making machinery has been supplied to the governments of England, Spain, Prussia, Sweden, Russia, Denmark and Egypt, and large quantities of American arms and ammunitions have been shipped to all quarters of the world. So manifest were the manifold advantages of the system of interchangeable construction as applied to the manufacture of arms that it has been extended to a great variety of other industries in which large numbers of the same kind of product are required—locks, sewing machines, steam valves, steam engines hardware and agricultural implements, clocks and watches. The idea of manufacturing watches by the interchangeable plan is distinctly American, and was first carried into effect on a large scale at Waltham, Mass., in 1854. Since that date watch factories have increased and multiplied in the land, and foreign nations have been compelled by American competition to adopt the idea which is the crowning triumph of the American system of interchangeable construction.

FROM MINE TO FURNACE.

By John Birkinbine, Pres. Eng. Club of Phila.; Past Pres. Am. Inst. M. E.

Fourth Paper.

IT would be interesting to discuss and illustrate the details of various methods employed in the preparation of iron ores for market, such as washing, concentrating and roasting; similarly, the subject of coking coal could receive attention, but if these matters were taken up they would extend the articles more than seems necessary. Therefore, beyond a few illustrations which have appeared nothing more will be said concerning the detail of beneficiating iron ore or coking coal; nor will the operation of some of the large and important quarries which supply flux to blast furnaces be taken into consideration, although at some, the blasting operations which have been carried on are of such magnitude as to entitle them to notice.

To trace the practical growth of pig iron production, researches need not go back 270 years to the first unsuccessful attempt at iron manufacture in Virginia, nor discuss the pioneer iron works erected at Lynn, Mass., in 1643, to treat the bog ores occurring near the coast, nor those following in Connecticut, Rhode Island, and New Jersey, nor need we recite the history of the older plants in New York, Pennsylvania, Virginia and Maryland, whose business records are associated with the history of the nation's struggle for independence.

A majority of middle-aged men now living have seen the years which mark the commercial development of this industry, for the last two decades and a half are the most pronounced in remarkable results.

Mr. James M. Swank, in his reports to the American Iron and Steel Association, states that the total output of pig iron in the United States in 1810 was 54,000 gross tons, increasing threefold to 1830, when it was 165,000 gross tons, and this again twofold to 1840, when it reached 286,903 gross tons; the output for 1850 being 563,755 gross tons, and for 1860, 821,223 gross tons. These figures show that while the production of 1860 was less than one-eleventh that of 1890, the banner year, when 9,202,703 tons were made, it was five times greater than in 1830. Taking the record for the past half century, the above data indicates that the pig iron output of 1890 was over thirty times that of 1840.

Until 1840, all of this iron was made with charcoal and by far the greater portion of it was still produced with that fuel in 1850. The year 1855 was the first recorded in which the production of pig iron by the use of anthracite coal exceeded that made with charcoal, and in that same year, the amount of pig iron made with bituminous fuel was but eight per cent. of the total output. However, from 1855, anthracite kept in advance of the use of charcoal, and in 1860, the relative proportions of iron made with the different fuels were practically twice as much charcoal pig iron as coke iron, and twice

BLAST FURNACES OF THE NASHVILLE STEEL, IRON AND CHARCOAL CO., BUILT BY GORDON, STROBEL & LAUREAU, PHILADELPHIA, PA

as much anthracite iron as charcoal iron.

It was in 1864, that the United States first made 1,000,000 gross tons of pig iron, falling below that figure in 1865, but exceeding it in 1866. It would, therefore, be unfair to use the comparatively small output for 1865 as a gauge for subsequent growth, and the production for twenty-seven years, beginning with 1866, will be taken. Table A demonstrates that the industry advanced so rapidly that in six years, namely, 1872, more than double the amount of pig iron was produced than was made in 1866; in fourteen years (1880), the output was over treble that of 1866; in sixteen years (1882), it was almost four times the output of 1866; in twenty-one years (1887), it was over five times the output of 1866; in 1889, twenty-three years after, it was over six times the output of 1866; in 1890, it was seven and five-eighths times the production of 1866. The product of 1891 was considerably below, and that of 1892 slightly below the output of 1890.

CHARGING A BLAST FURNACE BY SKIP.

This is truly a remarkable record of progress, and one which has never been

STORING AND HANDLING ORES, FLUX AND PIG-IRON.

duplicated in this or in any other country in a similar interval of time.

TABLE A.—Annual production of pig iron in the United States from 1866 to 1892.

	Recorded Number of Blast Furnaces.	Number of Blast Furnaces Operating at Close of Year.	Production Gross Tons of 2,240 Pounds.
1866....	—	—	*1,206,663*
1867....	—	—	1,305,023
1868....	—	—	1,431,250
1869....	—	—	1,711,287
1870....	—	—	1,665,179
1871....	—	—	1,706,793
1872....	612	—	2,548,713
1873....	657	410	2,560,963
1874....	693	365	2,401,262
1875....	713	293	2,023,733
1876....	712	*236*	1,868,961
1877...	**716**	270	2,066,594
1878....	692	265	2,301,215
1879....	697	388	2,741,853
1880...	701	446	3,835,191
1881....	**716**	**455**	4,144,254
1882....	687	417	4,623,323
1883....	683	307	4,595,510
1884....	669	*236*	4,097,868
1885....	591	276	4,044,526
1886....	577	331	5,683,329
1887....	583	339	6,417,148
1888....	589	332	6,489,738
1889....	570	344	7,603,642
1890....	*562*	311	**9,202,703**
1891....	569	313	8,279,870
1892....	564	253	9,157,000
A total output for 27 years of			105,712,591

of which 65,571,334 tons were produced in the decade just closed. The maxima are in full-faced figures, the minima are in italics. The pig iron produced in twenty-seven years, if run in a solid mass, would cover one square mile to a depth of nearly twenty feet.

DISTRIBUTION OF THE PRODUCT.

The statistics, collected from the manufacturers and published by the American Iron and Steel Association, show a total production of pig iron for the year 1892 of 9,157,000 gross tons, made in about 300 furnaces, which were in operation for some portion of the year, although but 253 were active at the close of that year.

Of the total output, 6,822,266 gross tons, or about seventy-four and a half per cent., was made by using coke or bituminous coal; 1,797,113 gross tons, or nineteen and a half per cent., was made by using anthracite fuel in whole or in part, but only 229,020 gross tons, or two and one-half per cent. of the total output, was smelted with anthracite coal alone; 537,621 gross tons, or six per cent., were made with charcoal as fuel.

Of the total production, 4,444,041 gross tons, or about forty-eight and one-half per cent., were classed as Bessemer pig iron for the production of steel chiefly by the acid process.

The quantity of domestic spiegeleisen and ferro-manganese produced was 179,131 gross tons, or about two per cent. of the total pig iron made in 1892. Practically all of this was used in steel manufacture.

At the close of 1892 the stocks of pig iron in makers' hands was 506,116 gross tons, or about five and a half per cent. of the total output.

Pennsylvania is credited with making 4,193,805 gross tons of pig iron, or nearly forty-six per cent. of the total output for 1892, which still maintains this State in advance of all others.

Ohio ranks second with 1,221,913 gross tons, or thirteen per cent. of the total.

Illinois advanced last year to third place in order of production, with an output of 949,450 gross tons, or over ten per cent. of the total; and

Alabama is fourth in importance, with a production of 915,296 gross tons, or almost ten per cent. of the total.

Pennsylvania and Ohio together produced 5,415,718 gross tons, over fifty-nine per cent. of the total output, and the aggregate of the four States, Pennsylvania, Ohio, Illinois and Alabama, was 7,280,464, or over seventy-nine per cent. of the country's production of 1892.

COMPARISON WITH OTHER COUNTRIES.

The year 1890 is memorable as placing the United States in the lead, which lead has since been maintained, our output of pig iron being larger than that of any other nation, and our development may be emphasized by a comparative statement of the product by

various countries within late years. (See Table B.)

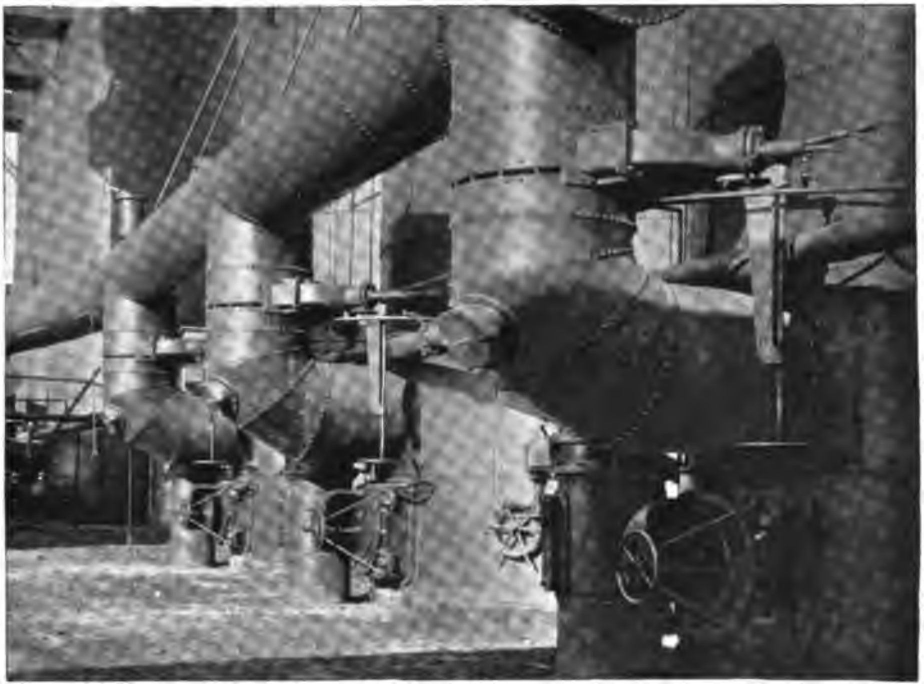
An examination of the published tables of production of pig iron in this and other countries gives a close approximation, although not an absolute

TABLE B.—Annual production of pig iron in various countries from 1866 to 1892, inclusive.

	Gross Tons of 2240 lbs.		Metric Tons of 2204 lbs.	
Years.	*United States.*	*Great Britain.*	*Germany.*	*France.*
1866	1,205,663	4,523,897	996,738	1,260,348
1867	1,305,023	4,761,023	987,163	1,229,044
1868	1,431,250	4,970,206	1,200,288	1,235,308
1869	1,711,287	5,445,757	1,356,965	1,380,964
1870	1,665,179	5,963,515	1,345,520	1,178,115
1871	1,706,793	6,627,179	1,491,477	859,641
1872	2,548,713	6,741,929	1,988,394	1,217,838
1873	2,560,963	6,566,451	2,240,574	1,381,000
1874	2,401,262	5,991,408	1,906,262	1,616,000
1875	2,023,733	6,365,462	2,029,389	1,668,000
1876	1,868,961	6,555,997	1,846,345	1,635,000
1877	2,066,594	6,608,664	1,932,725	1,507,000
1878	2,301,215	6,381,051	2,147,641	1,521,000
1879	2,741,853	6,009,434	2,226,587	1,600,000
1880	3,835,191	7,721,833	2,729,038	1,725,000
1881	4,144,254	8,377,464	2,914,009	1,886,000
1882	4,623,323	8,493,287	3,380,806	2,039,067
1883	4,595,510	8,490,224	3,469,719	2,069,430
1884	4,097,868	7,528,966	3,600,612	1,872,000
1885	4,044,526	7,297,295	3,687,433	1,630,648
1886	5,683,329	6,870,665	3,528,658	1,516,574
1887	6,417,148	7,441,927	4,023,953	1,567,622
1888	6,489,738	7,898,634	4,337,421	1,683,349
1889	7,603,642	8,245,336	4,524,558	1,733,964
1890	9,202,703	7,875,130	4,637,239	1,962,196
1891	8,279,870	7,406,064	4,452,019	1,919,185
1892	9,157,000	6,616,890	4,793,023	2,022,989

	Metric Tons of 2204 lbs.			
Years.	*Austro-Hungary.*	*Sweden.*	*Belgium.*	*Russia.*
1866	319,709	230,132	482,704	......
1867	361,038	253,493	423,069	......
1868	425,071	263,042	435,754	......
1869	450,567	292,082	534,319	......
1870	452,244	300,470	565,234	354,032
1871	476,627	298,893	608,248	353,710
1872	531,850	339,559	654,065	393,065
1873	594,980	345,872	606,173	378,387
1874	545,742	327,797	531,560	374,355
1875	504,347	350,694	541,790	420,484
1876	400,425	352,622	490,508	......
1877	388,230	344,484	470,488	369,732
1878	434,250	340,797	528,954	410,994
1879	404,160	342,486	453,000	429,865
1880	464,234	405,713	608,084	441,285
1881	539,646	435,428	624,736	462,027
1882	611,453	398,945	727,000	498,400
1883	701,037	422,627	783,433	......
1884	734,346	430,534	750,812	......
1885	714,784	464,737	712,876	527,526
1886	703,350	442,457	701,277	......
1887	704,532	456,625	755,781	532,649
1888	790,227	457,052	826,850	666,922
1889	816,156	420,665	832,220	745,872
1890	925,308	456,102	787,838	*911,854
1891	......	490,913	684,126	......
1892	......	......	768,000	......

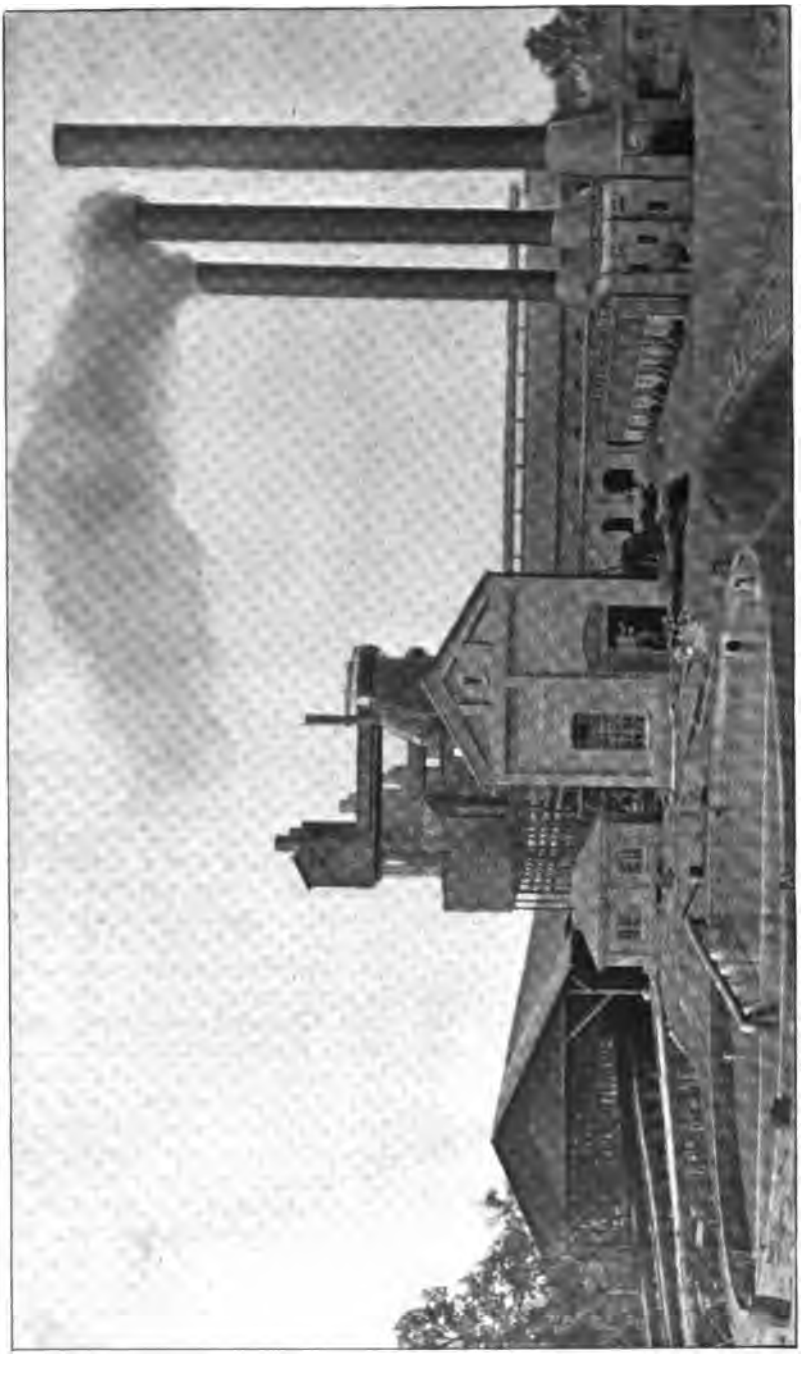
*Gross tons.



AT THE BASE OF A SET OF HOT BLAST STOVES.

determination of the figures, for the reason that it is not always possible to obtain contemporaneous data for the different countries. However, taking the most reliable records, we find that Great Britain first made 1,000,000 gross tons of pig iron per annum in 1835, but the United States did not reach that figure until twenty-nine years later, namely, 1864, in which year Great Britain produced 4,750,000 tons. In 1866, the commencement of the period under discussion, the United States produced one-fourth of the annual output of Great Britain, and approximated the output of Germany and France. For four years following the United States, Germany and France kept well together in output. Great Britain produced 2,000,000 tons of pig iron in 1847, twelve years after it had made 1,000,000 tons; but the United States reached this figure in 1872, eight years after it had made 1,000,000 tons. It was then twenty-five years behind Great Britain. Germany made 2,000,000 tons in 1873, and France did not reach the production of 2,000,000 tons until 1882.

After an interval of seven years from the date that Great Britain reached 2,000,000 tons of pig iron per annum, namely, 1854, that nation made 3,000,000 tons, and the United States did not cover the same ground until an interval of eight years, namely, 1880, while it took Germany nine years, namely, to 1882, to make this product. France has never yet reached an annual product of 3,000,000 tons. After another interval of nine years, viz.: 1854 to 1863, Great Britain added another million to its output, making the production 4,000,000, but the United States covered this ground in one year, being at that time eighteen years behind Great Britain, and it took Germany five years to increase its output from 3,000,000 to 4,000,000 tons, reaching the latter figure in 1887. An interval of five years sufficed for Great Britain to reach



A LARGE BLAST FURNACE PLANT.

a production of 5,000,000 tons, in 1868, and a similar interval brought the United States to the same output in 1886. Germany has never reached 5,000,000 tons. To pass the figure of 6,000,000 tons annual production, Great Britain required three years more, while the United States reached the same figure in one year, making the latter country sixteen years behind the former. In nine years for Great Britain and two years for the United States, each of these countries passed the production of 7,000,000 gross tons viz.: in 1880 and 1889, respectively.

Great Britain's largest pig iron output was in 1882, when 8,493,287 gross tons were produced; the United States' maximum annual output was in 1890, viz.: 9,202,703 gross tons. Germany's greatest output was in 1892, when 4,793,023 metric tons were produced, and the largest output for France was 2,069,430 metric tons in 1883.

Of the other pig iron producing countries Austro-Hungary, Sweden, Russia, Belgium, Italy, Spain, Canada and India, none have produced in any one year 1,000,000 gross tons. The largest reported output from Austro-Hungary was in 1890, when 925,308 metric tons were produced; that of Sweden was in 1891, viz.: 490,913 metric tons; the maximum output for Belgium was in 1889, when 832,220 metric tons were made, and in Russia the data have been so irregularly published as to make the figures uncertain, the report of 1890 of 911,854 metric tons being the largest published output. Spain produced 243,366 tons in 1890; Italy produced 14,346 tons in 1890; Canada produced 27,044 tons in 1892 (the year ending June 30th, 1892), and India 28,295 gross tons in 1890. A number of other countries produce iron, but only in comparatively small quantities. Statistical data for Great Britain covering the year 1892 show that 6,616,890 gross tons of pig iron were made. The United States therefore produced over thirty-eight per cent. more pig iron in 1892 than Great Britain.

One of the factors which has aided in securing the large annual output of 9,202,703 gross tons of iron in late years is that from seven to ten per cent. of this never took the form of pig iron. The advances made in our large steel works demand economies in every department, and instead of running the metal from the blast furnaces into molds in pig beds, allowing it to cool and then burning fuel to bring it again into a molten state, so as to feed it to converter or furnace, the iron is run from the blast furnace into ladles, carried on railway trucks and on these conveyed to the steel works for conversion. Each year has shown an increase in the quantity of iron thus treated, and in the year 1892 between 600,000 and 700,000 tons of molten iron was taken in this direct manner from blast furnaces to the steel converting plants. We may also expect this practice to continue to expand in other special industries.

When the practices of our great steel works are compared with the older methods, we understand why steel rails cost less than iron rails, or why steel plates undersell standard brands of plate iron. In these modern plants, the cold iron ore, fuel and flux enter the furnace and the cold or nearly cold finished steel plate, bar or rail is handled at the shears, drill press or punch, but at no intermediate point in the manufacture is the metal produced cold or below a temperature for convenient manipulation in rolls or under hammers.

Another factor which has aided the development of the pig iron industry is the association of the blast furnace and the chemical laboratory. The older empirical tests of bending a bar of iron to determine whether it was "cold short," "red short" or "neutral," or of noting the mere physical structure or fracture to recognize iron of foundry or mill grade, while serviceable still, have been supplemented by chemical analyses; and the percentage, or oftener the fractions of one per cent. of carbon, and the form in which it exists, of phosphorus, manganese, sulphur, silicon, etc., are now the generally accepted criterions of merit.

But the chemical laboratory would fulfill but a part of its functions without

a practical and technical application of the results there obtained, and to the intelligent, progressive energy and conscientious attention to details which have characterized many blast furnace managers, the people of the United States are largely indebted for the position which our country has taken as a producer of pig iron.

As a rule the efforts of this class (practically a creation to meet peculiar business requirements) are scarcely appreciated, for it is not only the manager who, with well-equipped blast furnace and rich ores, makes a brilliant record, but also he who, with inefficient appliances, lean or refactory ores and varying mixtures, accomplishes what a few years ago would have been considered impossible, who should share in the credit of the good work accomplished.

The structural features and the mechanical appliances introduced have done much to advance the possibilities of pig iron production, and have given the means of constructing, operating and successfully handling the product of our large blast furnaces, while permitting the smaller plants to work with greater economy. With the appliances in use at what were modern furnaces a quarter of a century ago, it would be practically impossible to handle the material supplied to, and the metal and slag flowing from, some of the larger blast furnace plants of to-day.

Another aid in securing the present position of the United States as a pig iron producer is the study which the consumers have given to the character and qualities of the pig iron which they use. While this investigation outside of the steel works has not been as general as is desired, there is a large share of credit due to the users of pig iron for the time and money expended in experimenting upon various grades and compositions of iron to secure certain results.

It has been but a few years since attention was directed to the remarkable influence which a small percentage of aluminum exerted upon cast-iron, one-half of one per cent. being sufficient to make a material change in certain physical features of the cast metal. The large amount of speigeleisen and ferro-manganese which has been produced and used in this country makes familiar the influence of manganese upon iron, and has caused it to be studied thoroughly. A series of very careful tests and examinations as to the influence of silicon upon iron, and the manufacture of ferro-silicon has also attracted attention, and lately we have learned from official tests of the influence exerted upon iron for armor plate by a small percentage of nickel.

All of these indicate that attention has been and is now devoted to the chemical and mechanical properties of iron both by those who make and those who use the metal. In the Mining building of the Columbian Exposition there is an instructive suite of iron alloys exhibited by a British firm making these a specialty, which show the attention devoted to the influences of phosphorus, manganese, silicon, chromium, etc., upon iron, and invite attention to the uses of such alloys.

It would be ungenerous, in noting some of the causes which encouraged the marvelous development of our pig iron industry, to omit mention of the assistance rendered by organizations and by the technical and trade press. The generous interchange of experiences brought about by social acquaintance, the reading and discussion of papers at the meetings of technical, engineering and trade organizations, have been of great assistance to many who control our blast furnaces and other industries. The liberal publication of technical and commercial data has, through the medium of a number of special publications, lifted many out of ruts which they would naturally follow in practically isolated locations without the knowledge of what was accomplished and how results were attained elsewhere. The collection and prompt publication of statistical information has been of marked service, and much of the data herein presented is proof of the value which the manufacturers of pig iron place on this feature. With-

out their cordial co-operation and confidence this data would not be obtainable, but with their active interest the publication within four weeks of the complete statistics of pig iron production for the year 1892 is most creditable to Mr. Swank and his associates in the American Iron and Steel Association. The figures represent returns from the 564 blast furnaces of the United States now considered as active; they give the number of furnaces in blast or idle, with the amounts of iron made by different fuels and of special character in each producing State, and in some instances of districts in a State, and the stock of iron on hand is also stated in the same detail.

THE LIMITATION OF ENGINE SPEED.*

By Chas. T. Porter.

THE practical limitation to high rotative speed in stationary reciprocating steam engines is not found in the danger of heating, or of excessive wear. The causes of both these, it is now well understood, are to be looked for in defects of design or construction, commonly of both, as they generally go together, and where these do not exist to a degree which is of a practical moment, a bar to the proper employment of higher rotative speed appears long before a tendency to heat or wear is to be observed. Correct designs are now generally followed, in both the fixed and the moving parts of steam engines, and a high degree of truth is readily attained in their construction, so that it has come to be a simple matter to make engines which can be run at very high speed, quite free from either of these difficulties.

Contrary to the general belief, no objection to very rapid rotation is afforded by the development of centrifugal force in the fly-wheel or band-wheel. The wheels of high-speed engines have generally solid rims, and no case of their bursting has, I believe, ever been known. Disasters from this cause have been confined to engines not designed to be run at high speed, and have sometimes occurred when the speed was only slightly accelerated above the normal rate. In these cases the wheels have been built in segments, with surprising disregard of necessary strength in the flanges and bolts by which the segments were held together.

Again, an objection to very high speed is not found in a tendency to knock on the centres. In a properly designed and constructed engine, in which the valves are correctly set, and which is run by steam, high speed tends to silent running. Noise from bad design or bad work, from insufficient lead given to the valves, and from water in the cylinder, is excluded from consideration. It is admitted, with pride, that the bad consequences of these defects are aggravated by high speed. This revelation of them has wrought an entire change in engine construction, not yet completed, and even makers of slower speed engines have largely profited by it. But it is obvious that there is now no excuse for their existence. The only legitimate cause of knock on the centres is loose boxes, and knock from this cause is softened as the speed is increased, and at extremely high speed will disappear

* From a paper presented at the International Engineering Congress at Chicago.

entirely, owing to the force of the steam at these points being absorbed in overcoming the inertia of the reciprocating parts.

Vibration is not an objection to very high speed, because it is an easy matter so to design and construct an engine, and balance the running parts, that it shall be free from vibration at any speed whatever. Again, very high speed is not objectionable, *per se*. If an engine runs in silence, completely free from vibration, without any tendency to warm, and without wear of any running part, its very speed renders it an object of especial admiration, even to those to whom such speed is new. Whenever extremely high speed in a steam engine has caused any other feeling in the beholder than that of admiration, it has always been the case that it has been attended with something annoying, a noise, or a jar, or some uncomfortable action, which ought not to have existed.

All this being true, there still remain two considerations of a controlling nature, which require that the rotative speed of engines shall be kept within moderate limits. The first of these is, that engines ought not to be run as fast as they can be. It must, on reflection, be obvious to every one, that an engine should be capable of running, and that too with entire satisfaction, so far as its motion is concerned, a great deal faster that it is run. This is the solid ground of security and confidence. It means peace and comfort, and helps to make men sleep well o' nights. It means long life to both engine and builder.

The second objection to the employment of extremely high speed is a very serious one indeed. It is the large amount of waste room in the port, which is required for proper steam distribution. In the important respect of economy of steam, the high-speed engine has thus far proved a failure. Large gain was looked for from high speed, because the loss by condensation on a given surface would be divided into a greater weight of steam, but this expectation has not been realized. Far from it. The performance of this class of engines shows, instead, a positive, and in some cases a large, loss in economy. For this unsatisfactory result, we have to lay the blame chiefly on the excessive amount of waste room. It has been already pointed out by Mr. Harris Tabor, that the ordinary method of expressing the amount of waste room, in the percentage added by it to the total piston displacement, is a misleading one. It should be expressed as the percentage which it adds to the length of steam admission, and then every one would see what a serious thing it is. For example, if the steam is cut off at one-fifth of the stroke, eight per cent. added by the waste room to the total piston displacement means forty per cent. added to the volume of steam admitted. Under these circumstances it is obviously the duty, and for the interest, of builders of high-speed engines to adopt every expedient for reducing the amount of waste room, that can be done consistently with the proper admission and discharge of the steam. For this, the first requisites are moderate piston speed and longer stroke.

Engines of four, five and six feet stroke may properly be run at from 700 to 800 feet of piston travel per minute, but for ordinary sizes I would recommend and urge that 600 feet per minute be taken as the limit of piston travel, under all circumstances. This will give from 300 revolutions per minute with twelve inches stroke to 100 revolutions per minute with thirty-six inches stroke, with which purchasers ought to be satisfied. I would ask builders, in their own interest, to resist the temptation to get the utmost out of a given engine, and to set their faces like a flint against the demand for short-stroke engines, which shall occupy but little room, and from which the required power can be got by speeding up beyond the limit here proposed.

MODERN GAS AND OIL ENGINES

By Albert Spies, Mem. Am. Soc. M. E.

Eighth Paper.

IN connection with the different ignition methods referred to in the preceding paper, it may not be amiss to mention that in the case of engines using either flame or tube igniters the consumption of gas by the igniting or heating burners is an item not always duly taken into account, and may assume appreciable proportions. Where gasoline or some other oil is used in such engines instead of gas, and where the latter is not to be had, the gas flame must, of course, except in a few engines of special design, be supplanted by an oil torch, and the same additional fuel consumption, above that taking place in the cylinder of the engine itself, is there encountered, the torch, moreover, being a rather undesirable annex to the whole outfit. These circumstances have, in a great measure, helped to stimulate the improving of electric igniting devices, and several of them are now affording very satisfactory accounts of themselves. This much may already have been gathered from what has gone before. With the electric igniter there is, of course, to be considered the expense of the battery which furnishes the electric current, but this has been claimed, and with good reason, to be a very small proportion of the whole operating expense,—a much smaller one, in fact, than that represented by the gas or oil cost in a flame or tube igniter. It would seem to be a pretty fair conclusion, under the circumstances, that electric igniters are destined to a yet wider application and a growing share of favor.

Not less important than the methods of igniting are those of governing, and considerable ingenuity has been expended for years past in developing various contrivances designed to satisfactorily solve the gas engine governor gear problem. At first thought, some sort of throttling gear by which the gas or oil vapor supply to the cylinder is gradually reduced as the speed increases, and vice versa, is apt to suggest itself as a desirable one, and, as a matter of fact, many gears of this kind have been made and are used, both Lenoir and Hugon having followed this method of governing in their early engines. Its wastefulness, however, becomes apparent on even slight consideration, so that one may well wonder that at this late day the throttling governor is still countenanced in gas engine practice. It is obvious that if, with such a governor, the volume of gas or oil vapor admitted to an engine cylinder is diminished, the volume of air admitted is correspondingly increased, and it is well known, too, that the limits of variation permissible in explosive mixtures of gas and air are comparatively narrow, so that if, in a total volume of mixture, the volume of gas either exceeds or falls short of a certain, elastic proportion, no explosion can be produced. While, therefore, a gas throttling governor may either increase or diminish the force of the explosions in the engine

cylinder by varying the strength of the gas and air mixture between these limits, yet if one of the limits be passed, and the gas volume, for instance, be too greatly diminished, ignition of the mixture will be missed and whatever to increase, gas being simply pumped through the cylinder and wasted until its proportion is again increased, by the subsequent opening of the gas valve to that point where the mixture once more becomes explosive.

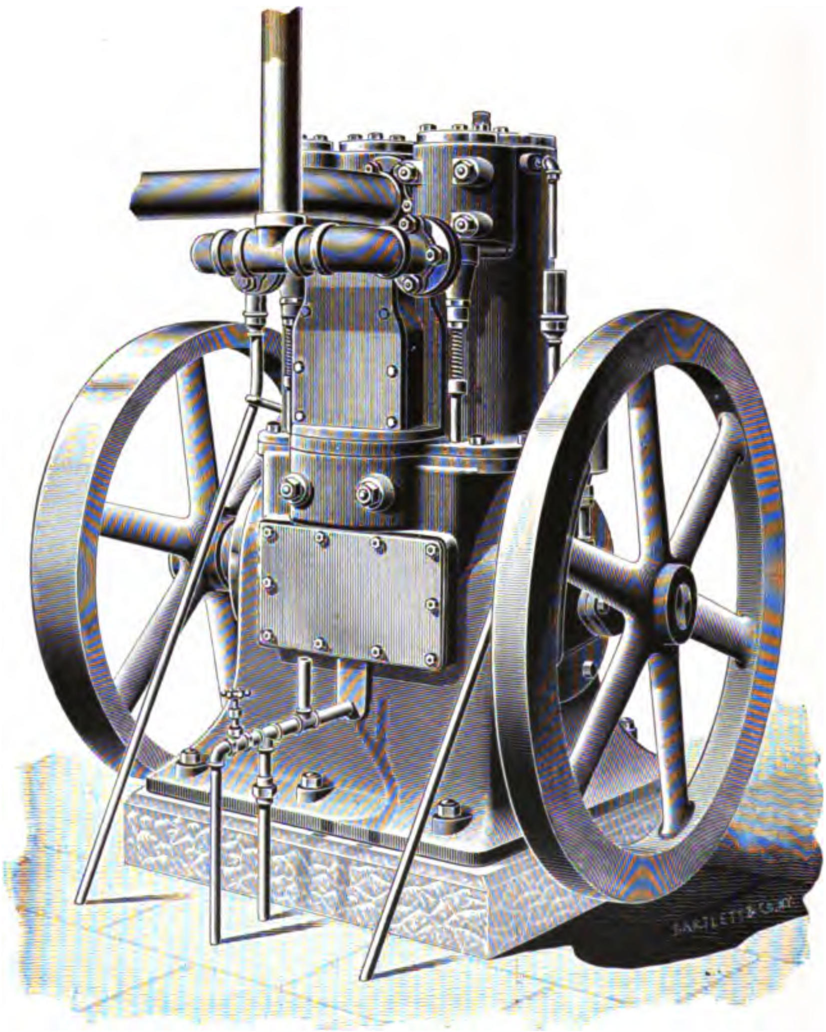


FIG. 115.—THE PITTSBURGH ENGINE, BUILT BY THE FUEL GAS AND MFG. CO., PITTSBURGH, PA.

gas has been taken into the cylinder will then be discharged into the exhaust pipe unburnt and without having given up any of its energy. Under these circumstances the engine will work exactly as though no gas whatever had been admitted, and the speed will cease

No better evidence is needed of the fact that the wastefulness of the throttling governor method has met with a fair share of recognition, than the extended application which for years has been given to what have been termed "hit-and-miss" governors. With

these the strength of the explosive gas and air mixture is never changed, but the number of explosions in the engine cylinder in a given time is varied to suit the prevailing requirements, being increased when the speed falls below, and decreased when it rises above a certain normal; or putting it in a slightly different way, when the speed falls off, the governing device hits the stem of the gas supply valve, causing the latter to open and admit gas into the cylinder, while when the speed becomes too high, the governor by changing its position, misses the gas valve stem, the valve consequently remains closed and no working charge reaches the cylinder.

One objection to this method of governing always has been that it gives the engine a jerky, unsteady motion which is fatal to success in electric light work, and in order to overcome this, some engine builders now provide the governor cam which strikes against the gas valve spindle with several steps, so that instead of being either full on or full off, the gas valve may be opened through intermediate degrees. The strength of the explosive mixture may thus be varied to some extent, but whenever the lower limit of gas percentage necessary to constitute an explosive charge is reached, the gas valve is closed entirely, and the engine then runs without explosions until the speed again drops. The stepped-cam governor, in fact, combines a throttling with a cut-oft action.

The ideal method of governing, however, would seem to be one akin to that followed in modern, high-class steam engine practice,—one by which the strength of the working charge would be kept always the same and only the quantity for each working stroke would be varied. In all processes of combustion there is a certain percentage of oxygen, which, by combining with a certain percentage of combustible, produces a maximum effect, and any variation from these relative proportions will represent a loss of efficiency. This is fully as true of the combustion of gas in a gas engine cylinder as of the combustion of any other kind of fuel in any other place, and the economic bearing of maintaining a constant and certain strength of explosive mixture in gas engine work will, therefore, be at once recognized.

An engine in which advantage has been taken of this circumstance is that recently put on the market by the Fuel Gas and Manufacturing Company, of Pittsburgh, Pa., and known as the Pittsburgh engine. In external appearance it strikes one much as one of the well-known Westinghouse steam engines. As in these, a crank case encloses the bearings and lower end of the cylinders. This case is filled almost up to the shaft with a mixture of oil and water, into which the crank shaft and connecting rods splash at every revolution, so as to completely deluge the bearings, piston and interior of the cylinders, thereby not only affording copious self-lubrication, but also cooling the piston. Oil for the crank case is introduced through the main bearings, which are supplied from the only two oil cups on the entire engine. A simple pipe connection with a city main supplies the necessary water. Another pipe, serving to carry off the overflow, is made, by means of a funnel head, to indicate the level of the lubricants in the crank chamber.

All the Pittsburgh gas engines are built with two cylinders on a single shaft, and, as usual, abnormal heating is obviated by the employment of water jackets. Each revolution made by the engine operates valves admitting the gaseous fuel alternately to the one or the other cylinder. As the period of admission is controlled by a positive action, the crank shaft receives an impulse once each revolution, no matter what the load, but the energy of that impulse is predetermined by an independent piston valve. In order that the maximum amount of energy may be developed by the explosion of the gaseous fuel, there is, as already explained previously, but one value that the relative amounts of gas and air can bear to each other, and the company design their measuring piston valve so that, it is claimed, it always admits gas and air in their correct proportions for

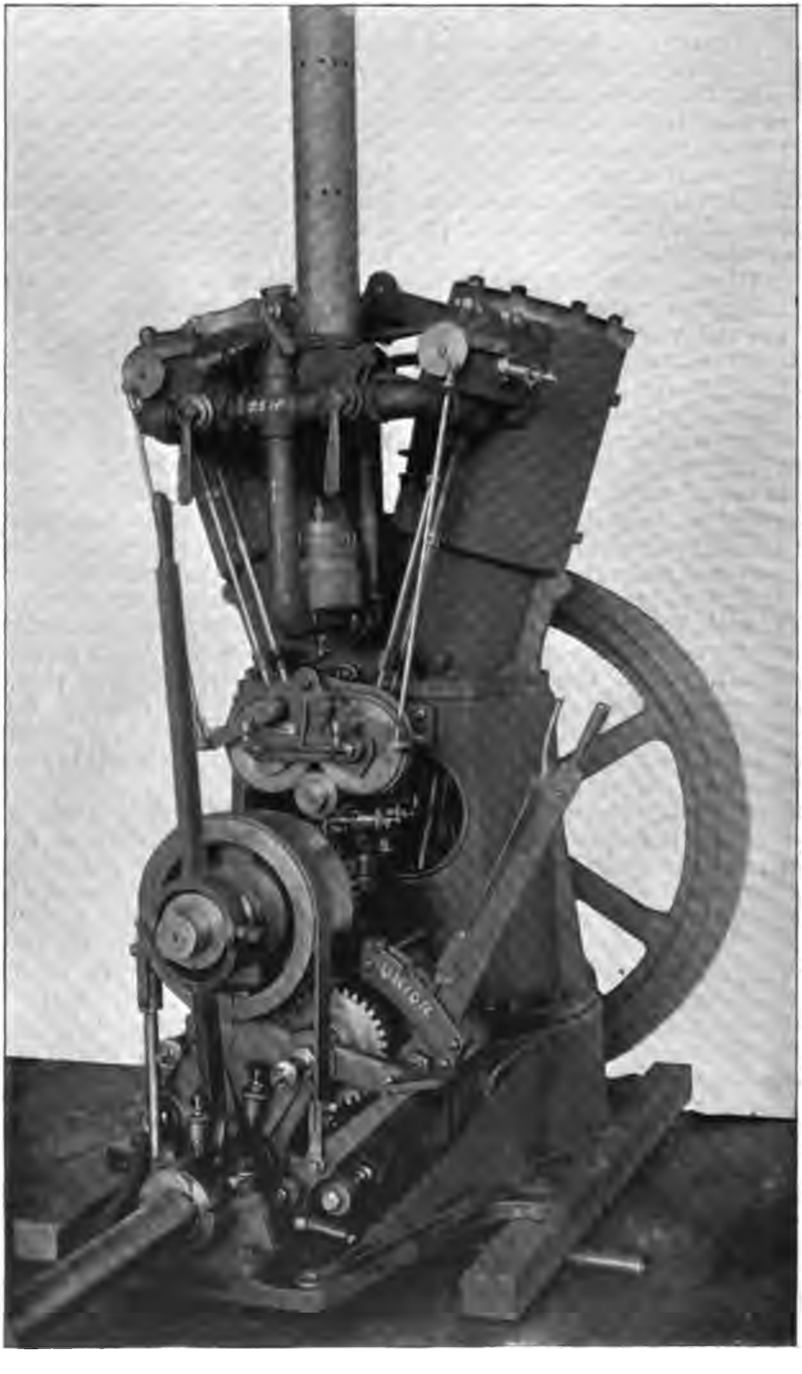


FIG. 116.—TWENTY-FIVE HORSE-POWER UNION MARINE ENGINE.

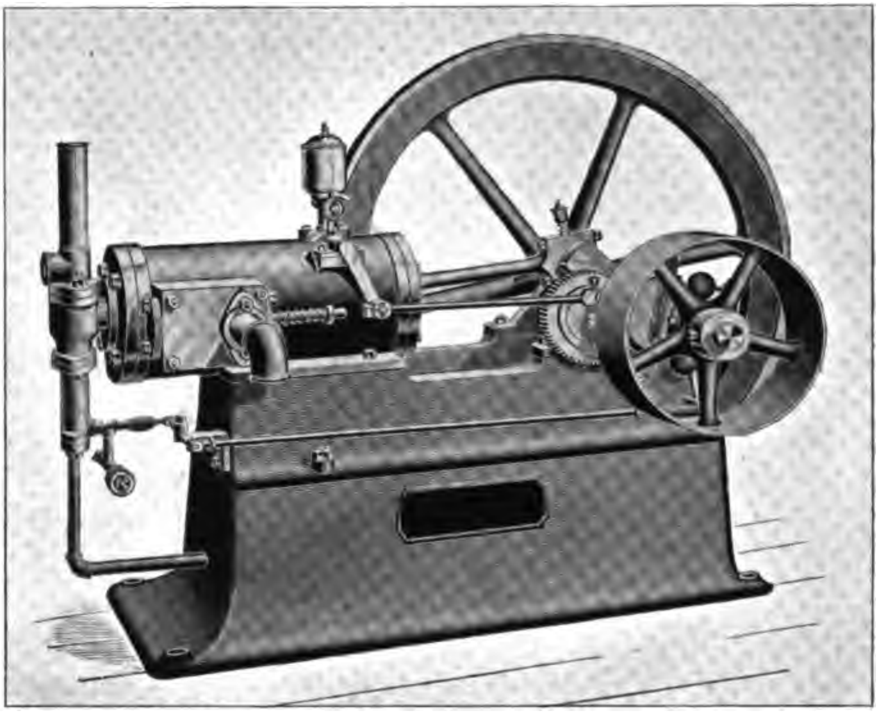


FIG. 117.—THE CHARTER ENGINE, BUILT BY THE CHARTER GAS ENGINE CO., STERLING, ILL.

producing the desired maximum result, but at the same time varies the total amount of mixture directly as the work of the individual piston stroke. The governor is mounted upon the shaft, between the cranks, and, by direct connection between the eccentric rod and valve stem, insures an accurate and positive travel to the measuring slide valve. The igniter employed is of the electric spark type. Unfortunately, more complete particulars of this engine are not available at the present time.

In connection with the Union engine, described in the preceding paper, and built, as there stated, by both the Union and the Globe Gas Engine Company, of San Francisco and Philadelphia, respectively, the illustration on the opposite page will prove interesting, representing, as it does, the latest type of double cylinder, marine engine of Union make, rated at twenty-five horse-power. This engine, according to advices received within the past few weeks from the builders, was completed only a short time ago, and is now in a schooner in San Francisco Bay giving highly satisfactory results. It is the first one of the kind that they have built, and is probably the largest marine oil engine now in use, except a four-cylinder engine of forty-five horse-power of somewhat different form which was turned out by the same builders a number of years ago. The main features of the engine are essentially the same as those of the horizontal Union stationary engine, shown in the September number ; the valves and igniting devices are similarly operated, and the same form of vaporizer as that then illustrated is used.

The propeller reversing gear shown tends to give the impression that there is considerable complication about the engine, but this will disappear upon closer study of the details. A muffler

around the exhaust pipe is used to deaden the noise of the exhaust. The schooner in which the engine is placed is 59½ feet long with 14 feet beam, and carries freight between San Francisco and Bodega Bay. On her trial trip over the Government course in San Francisco Bay she developed a speed of over 8 miles an hour. This was regarded as a very good showing, as the engine was new and stiff, and the boat was not built for speed. The owners

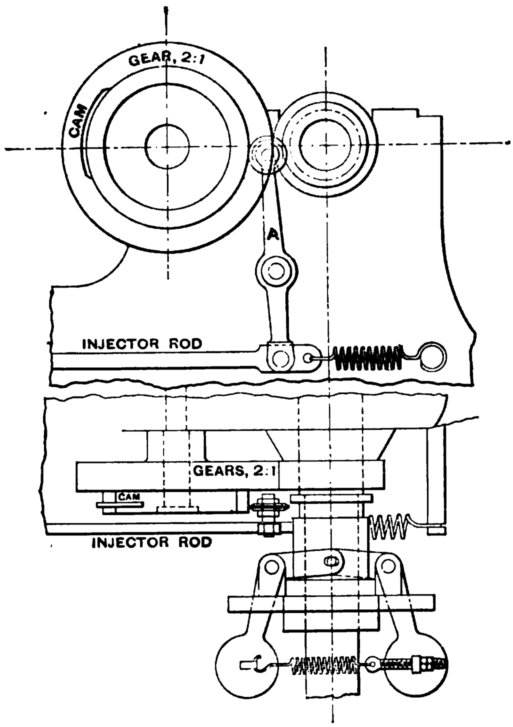


FIG. 118.—DETAILS OF THE CHARTER ENGINE.

of the vessel also have a 10 horse-power engine in one of their other boats.

As the last of the series of illustrations are presented those of the Charter gas and gasoline engine, which is made by the Charter Gas Engine Company of Sterling, Ill., and which in some respects is similar to the Caldwell-Charter engine described in one of the earlier papers. When using gasoline no carburetting device is used between the oil tank and the cylinder, but the oil is delivered directly into the suction pipe by a pump controlled by the governor, a few drops only being admitted at a time. There are three cut-offs between the tank and engine cylinder, viz., a cock at the tank, a throttle valve to regulate the amount of gasoline delivered, and the plunger of the pump just mentioned. The engine works according to the Otto cycle, the exhaust valve being pushed open at every other revolution by a rod worked through reducing gearing from the crank shaft. The arrangement of the gasoline pump and the manner in which it is controlled by the governor will be easily understood both from the general view of the engine and from the details shown in Fig. 118, the latter representing an elevation and a plan of the governor and its connections. The governor, it will be observed, is mounted on a sleeve on the main shaft, and when the governor balls, under the influence of unduly high speed, move outward, the sleeve is carried along the shaft and moves with it a cam roller, which is mounted loosely on the upper end of the rocker arm *A*. When so displaced, this cam roller is missed by the cam on the larger of the two gear wheels shown, and the rocker arm, which is connected with the injector rod operating the gasoline pump, remains undisturbed, and no gasoline is permitted to enter the suction pipe leading to the cylinder. When, on the other hand, the governor balls are in the position shown in the engraving, the cam on the larger gear wheel will, in the course of its revolution, come in contact with the cam roller on the arm *A*, force it over to the right, and cause a stroke to be made by the gasoline pump through the intervention of the injector rod. The displacement of the pump plunger then admits the proper gasoline supply to the suction pipe, and the entering air carries the oil along into the cylinder in which the mixture, after compression, is fired by a tube igniter. For engines above six horse-power a slightly different form of governor connection is employed, the working principle, however, being the same. The engine is turned out in sizes of from one and

one-quarter to thirty-five actual horse-power.

Before finally leaving the subject, the writer would attempt to forestall criticism on the score of incompleteness of the series of articles presented by stating that no attempt could be well made to embrace in them all the engines of the class considered which are now in use and built in different countries. It was deemed advisable, in fact, at the outset to try to present only engines of English and American make, and such foreign designs as were represented in English and American markets, and even this undertaking was found beset with many difficulties. Aside from the fact that the addresses of some makers of engines could not be ascertained, there were a number of builders who simply ignored requests for information, and others again who flatly declined to furnish particulars of any kind. That the list of engines considered in these articles is by no means comprehensive is, therefore, natural.

AN EVAPORATIVE SURFACE CONDENSER.*

By James H. Fitts.

THE condenser herein described was built at the Virginia Agricultural and Mechanical College, at Blacksburgh, Va., after some observations were made on the rate of evaporation of water at different temperatures, and with a current of air passed over its surface. Its performance has been successful to such a degree that this paper is presented, in the belief that it will be of general interest to the profession, and that it gives a practical solution of the question of condensation of vapor with a small water supply.

The condenser consists of two rectangular end chambers connected by a series of horizontal rows of tubes, each row of tubes being immersed in a pan of water. Through the spaces between the surface of the water in each pan and the bottom of the pan above, air is drawn by means of an exhaust fan. At the top of one of the end chambers is an inlet for steam, and a horizontal diaphragm about midway causes the steam to traverse the upper half of the tubes and back through the lower. An outlet at the bottom leads to the air pump.

The condenser, exclusive of connection to the exhaust fan, occupies a floor space of 5′ 4½″ x 1′ 9¾″, and is 4′ 1½″ high. There are twenty-seven rows of tubes, eight in some, and seven in others; 210 tubes in all. The tubes are of brass, No. 20 B. W. G., ¾″ external diameter and 4′ 9½″ in length. The cooling surface (internal) is 176.5 square feet.

There are twenty-seven cooling pans, each 4′ 9½″ x 1′ 9¾″, and 1 7-16″ deep. The pans have galvanized iron bottoms, which slide into horizontal grooves ¼″ wide and ¼″ deep, planed into the tube sheets. Wooden strips are fitted into the grooves below the bottoms. The tube sheets form the ends, and angle irons 1⅜″ x ¾″ x ⅛″ bolted to the galvanized bottoms, the joints packed with wooden strips, form the sides. The total evaporating surface is 234.8 square feet. Water is fed to every third pan through small brass cocks, and 1¼″ overflow pipes feed the rest. A wood casing connects one side with a 30″ Buffalo Forge Co.'s disk wheel, which is belted to a 3″ x 4″ vertical engine.

The action of this condenser is clear. The passage of air over the water surfaces removes the vapor as it rises, and

* From a paper presented at the International Engineering Congress at Chicago.

THE EDISON LABORATORY AT ORANGE, N. J.

chanted ground, wary of eye and limb. Of royal dimensions is the library ot that extraordinary man, whose youthful elbows often suffered from involuntary contact with the walls, and whose restricted quarters suggested Miss Mitford's bedroom, where, without getting out of bed, it was possible to light the fire, shut the door and open the window. The library is forty by fifty feet, vaulted by a ceiling forty feet high and encircled on three sides with graceful carved galleries, supported on pillars of iron. Book cases of rare and beautiful polished wood adorn the sides of the hall, and as we pass, glimpses are afforded of ancient and modern tomes, the rich fruitage of every scientific clime, from the sparse blossoms of early Greece, Arabia, Central and Northern Europe to the golden vintage of the present age. These literary treasure houses contain fully 40,000 works of reference, and are so formed as to constitute alcoves both on the lower floor and on the successive tiers of galleries. An Oriental flavor is imparted to the surroundings by a bank of flowers and palms, and a touch of refined and imaginative art is given by Bordiga's celebrated marble statue "The Genius of Light," purchased at the Paris Exposition of 1889 by Mr. Edison, and representing a winged figure poised on the shattered remnants of a gas lamp, while in its right hand it holds a brilliant incandescent lamp. Portraits of prominent scientists adorn the wall, flanked by busts of well-known naturalists and electricians, together with a series of semi-allegorical designs, representing the triumphs of the incandescent light.

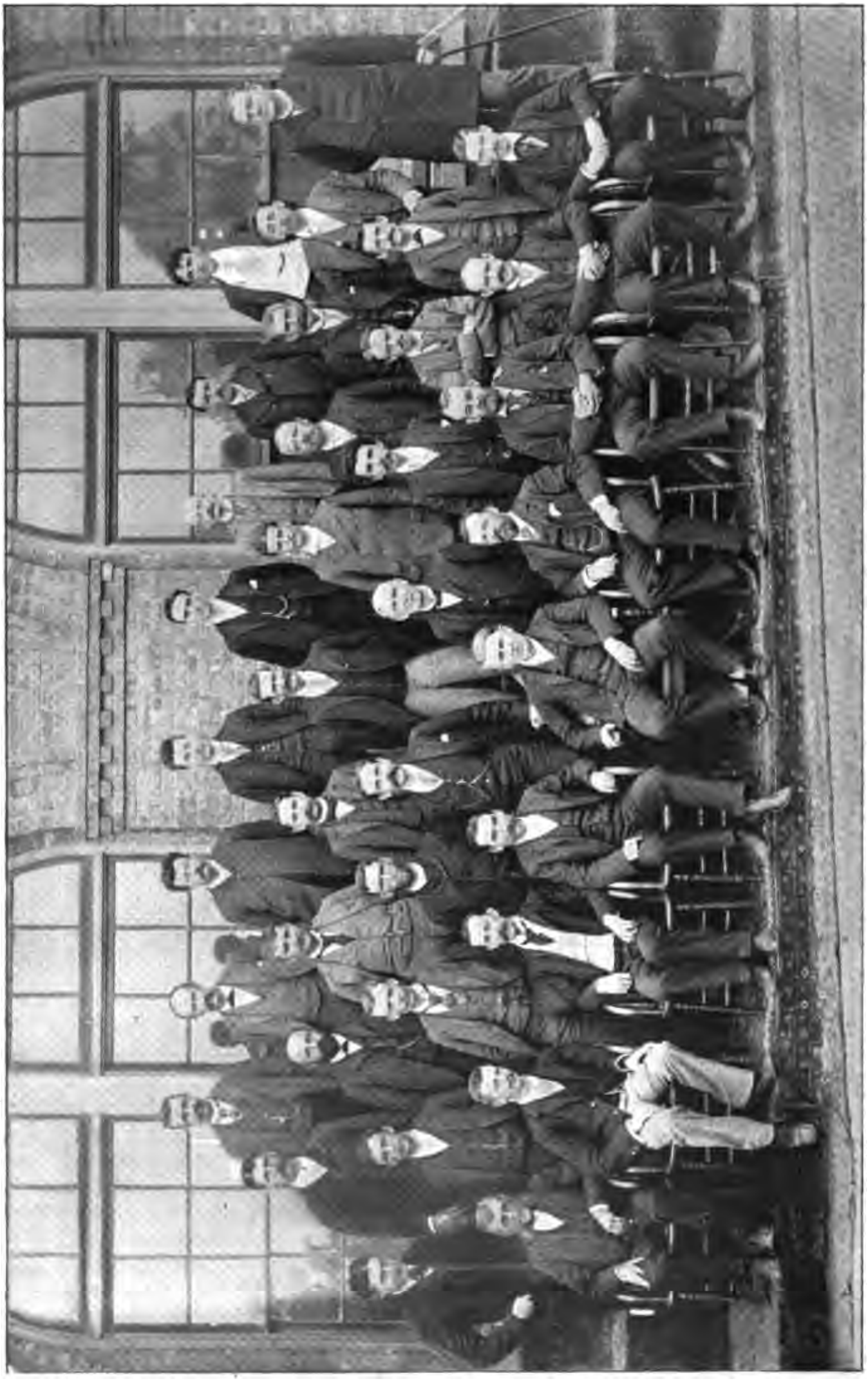
Models of dynamos and terrestrial globes meet us on every side, diversified by musical instruments, amongst which we notice several pianos and an electrical organ of rich and sonorous tone. We resist these seductions, one and all, despite the tempting lounges and chairs which invite to luxurious contemplation, but no combination of circumstances short of wild horses or a blizzard could induce us to slight the exquisite Tiffany-Kuntz collection of minerals and gems purchased by Mr. Edison at the Paris Exhibition, and which holds its glittering court in the recesses of the first gallery.

Here are crystals, transparent and translucent, wine-hued, crimson, rose and ocean-green, drenched with sunshine and with moonlit rays ; heaps of gems, cut and uncut, dusky garnets, royal amethysts, beryls and topazes, arabesques of copper on basic slabs, traced by tongues of fire, and ranging from argent to cramoisie noir ; here a grim meteorite, from Mexico, weighing 1500 pounds ; specimens of sulphide

and arsenic ores, realgar and oppiment, melting into the loveliest hues of dusky emerald and red ; further on a magnificent specimen of stibnite or crystallized sulphide of antimony, worth $100, and weighing thirty pounds, lifting its clustering spires of dull hued silver. Here are elfin embroideries of crystallized gold and radiating crystals of antimony, frost-like in their delicate sheen ; cubes of gallenite, grouped in 1000 fanciful forms like the architecture of a Niebelung city; pillars of tourmaline, rose and apple-green ; fragments of crocidolite, subtly limned like the bronze and gold of a cat's eyes ; a great mass of hornblende, white opaque, and shaped like a sullen tower of the middle ages ; portions of sheeny asbestos, bringing with them remembrances of Roman feasts ; blocks of velvet malachite, presenting the perfect semblance of emerald plush, and assuming an endless variety of forms, from the grim outlines of a dragon's maw to the cushioned recesses of a faerie throne ; blocks of quartz, rose, smoke color and amethyst ; petrified rainbows of marcassite and sphalerite, recalling the many hued Bridge of Asgard, agates in mathematical circles of blue and dove color, lemon and bronze gold ! But alack, what intoxication is this that beguiles our senses ? We are drunk with luscious color, as with the generous blood of grapes. Not thus may our task be accomplished, not thus may the sober duties of a veracious chronicler be discharged.

A CORNER IN THE LABORATORY LIBRARY.

The library did not always mirror its present aspect of comfort and beauty. Truth to tell, it was a comparatively gaunt and cheerless abode, depending solely on its literary treasure troves and scientific models for adornment, but on the occasion of Mr. Edison's forty-second birthday, the place underwent a magical transformation at the hands of the laboratory staff and workmen. Profiting by the convenient absence of their chief, these amiable conspirators



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EDISON AND HIS ORANGE LABORATORY STAFF.

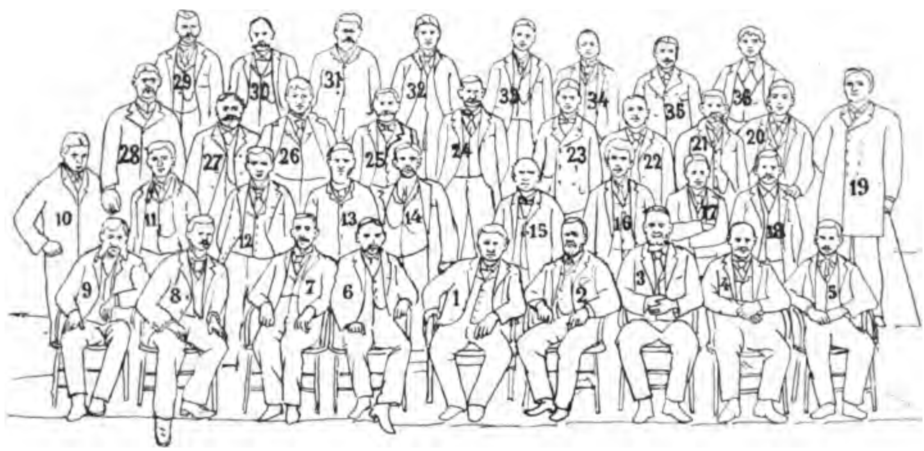
proceeded to revolutionize the howling waste. They covered the grim expanse of floor with soft Smyrna rugs, hung the walls with inviting pictures, decorated the middle ground with a tropical display of flower and palm, and scattered a profusion of tables around, solid, capacious and conducive to that squaring of elbows, indispensable to a proper "flow of soul." There are several of these inspirational pieces of furniture, disposed in the centres of the room and in the recesses at the side, and flanked by eighteen handsomely carved chairs, in oak and leather, embellished with the monogram—T. A. E. An especially inviting portion of this many-sided hall is the embrasure at the further end, wherein is placed a delicious old-fashioned fireplace, filled with logs, some enchanting easy chairs, and a reading table. The flames are playing merrily over the charred surface of the wood, awakening rosy flushes in the depths and filling the room with cosy crepitations. The hum and throb of distant machinery falls drowsily on our ears, the dying rays of the sun slant across the polished mosaic of the floor and the Eastern hues of the carpets. Dynamos and electric motors retreat to the peripheries of our consciousness. We sink into the luxurious depths of an arm chair, and gazing dreamily into the blackened recesses of the fireplace, are transported to that quaint hostelrie of the Canterbury Tales. Here we are :

Wel nine and twenty in a compagnie
Of sondry folk, by aventure yfalle
In felawship, and pilgrims were they alle,
That toward Canterbury wolden ride,
The chambres and the stables weren wide,
And wel we weren esèd atté beste."

In our ears still lingers the charmed numbers of that

"Strain most holy
The hoary minstrels sang in times of old."

In our drowsy memory stir pleasant recollections of travelers' tales, into our nostrils rises the steam of venison pasty and larded capon, and the fragrance of malvosie and sack. Alas! for the short-lived visions of the past. Suddenly into our ears, attent to the unfoldings of history's burning scroll, comes a piercing whistle, another and another, blent into a weird minor discord, which, unfortunately for musical sensibilities, retains its insistent query, and refuses to melt into its legitimate resolution. It is the signal for closing the works, and



1.—THOS. A. EDISON.
2.—CH. BATCHELOR.
3.—W. S. MALLORY.
4.—J. F. RANDOLPH.
5.—J. W. HARRIS.
6.—J. OTT.
7.—THOS. MAGUIRE.
8.—J. W. GLADSTONE.
9.—CH. BROWN.
10.—A. Y. STEWART.
11.—W. MILLER.
12.—J. W. AYLESWORTH.
13.—J. T. MARSHALL.
14.—A. E. KENNELLY.
15.—P. KENNY.
16.—W. K. L. DICKSON.
17.—T. BANKS.
18.—H. F. MILLER.
19.—A. T. E. WANGEMANN.
20.—H. J. HAGAN.
21.—W. S. LOGUE.
22.—WM. HEISE.
23.—R. LOZIER.
24.—E. W. THOMAS.
25.—F. P. OTT.
26.—F. A. PHELPS, JR.
27.—CH. WURTH.
28.—S. G. BURN.
29.—L. W. SHELDON.
30.—R. ARNOT.
31.—C. H. KAISER.
32.—J. MARTIN.
33.—H. REED.
34.—C. M. DALLY.
35.—F. C. DEVONALD.
36.—A. J. THOMPSON.

EDISON AND HIS ORANGE LABORATORY STAFF.

with its imperative mandate our poetic fabric tumbles about our ears. No longer are we

"In Southwerk at the Tabard,"

but in a nineteenth century library, replete with the distressing conveniences peculiar to that age. This royal billet, with its gnarled and knotted surface, its scaly bark, encrusted with lichen and powdered with ashes, its ligneous rings and its glowing heart of ruby, is nothing but a cunning counterfeit, wrought of iron and asbestos and lit by multitudinous jets of gas.

From this palace of enchantment we issue into the storeroom, which holds the most unique and comprehensive paraphernalia in the world. Here are specimens of every material which may possibly be needed in connection with Mr. Edison's experiments, and as the inventor's ideas are generally "sparks which flash, red illumed, from the anvil of the brain," brooking no delay in the process of incarnation, and as, moreover, there are no assignable limits to the scope and direction of his erratic genius, the utmost skill and research have been employed in bringing together this material basis for his research. Mr. Edison has challenged the skeptical to name one substance, organic or inorganic, which is not to be found in this unique collection. Every department of nature has yielded its tribute to the potent wizard, not merely the superficial products familiar to every day use, but those arcana which the ocean and nether world hold in their innermost depths. Space and strength fail us in the enumeration of that endless catalogue. Here

"A tortoise hung,
An alligator stuffed, and other skins
Of ill-shaped fishes,"

the bones of birds and animals, feathers, hides, teeth and horns, many sufficiently gruesome in form to suggest the perambulations of the nocturnal mare. Shining metals, lucent crystals, variegated minerals lie scattered in profusion; dainty shells and coral reposed amongst mosses and sea-weed, fragrant gums and spices recalled memories of the fair Babe of Bethlehem. Chalks, resins, salts and chemicals are heaped about in lavish plenitude, notwithstanding the fact that many of the latter represent a value of $300 an ounce. The collection embraces not only raw products, but specimens of every imaginary human industry. On the shelves rest piles of textiles, ranging from the coarsest sacking to a gossamer fabric, such as might well have been drawn through the golden ring of the Fairy Prince. These are flanked by metallic sheets of every description, while the floor is occupied by a motley crew of ropes, twines, bundles of brass and iron tubing, paper, oil cloth, gutta percha, leather, slabs of granite, marble, slate, etc., etc. A general and totally unclassifiable litter of trade devices are lying loosely around. A sanguinary meat chopper impedes our path in one direction and an ice cream freezer in another, offers its softer suggestions of summer nights and luscious syrups, while pickaxes, saws, coffee mills, wheelbarrows, ladders and what not bewilder our limited visual scope. Specimens of human manufacture, not only the limited appliances of the past, but the perfected outcome of the present, are fully represented, but in a profusion which forbids anything but the most superficial survey. It has been well said, in summing up the whole heterogeneous supply, that it comprises all the requisites of "a dry goods, grocery, drug, iron mongery, glass, chandlery, oil, paper, rubber, leather, grain, hardware, stationery, chemical and feather store all in one, and that there is not any article known to civilized man, from a bootjack to a locomotive, the materials entering into the manufacture of which could not be furnished from this storeroom."

From the storeroom we pass into the lower machine shop, devoted to the construction of the heavier mechanism used in dynamos, ore milling machines, etc., and are met by a bewildering din and clanking and throbbing as the great metallic giants sullenly perform their varied functions in the service of man. It is with feelings of overpowering wonder, not unmixed with awe, that we

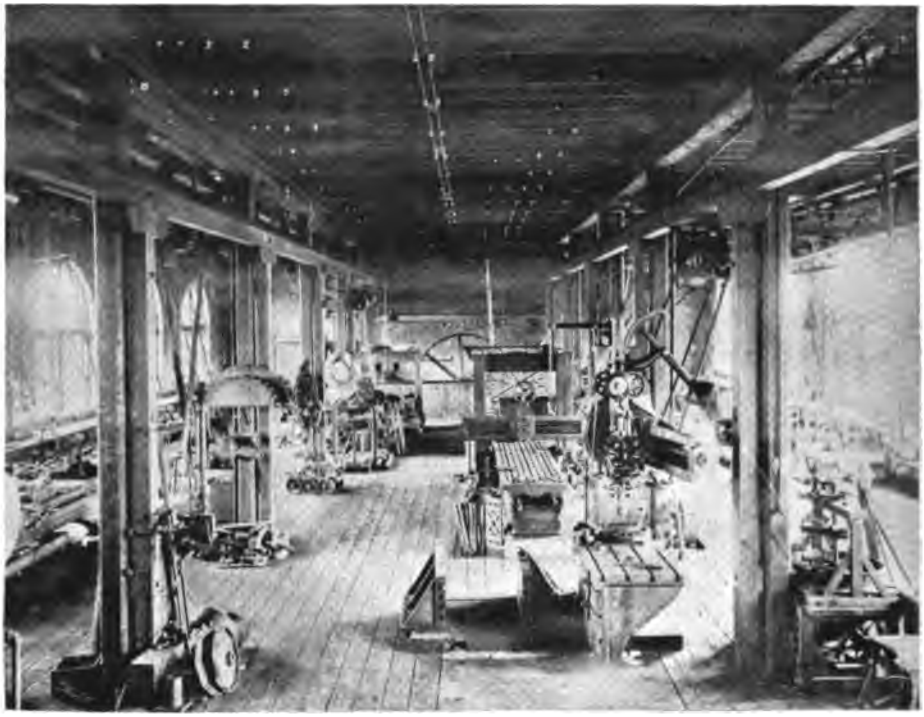
THE LABORATORY STORE-ROOM.

take cognizance of these embodiments of nineteenth century energy, these swiftly rotating wheels, this pulsating machinery, these mysterious motions of drilling, cutting, pressing and boring, outcomes of an invisible and irresistible force. Truly, as Holmes hath it,

"After all, it is the imponderable that moves the world, heat, electricity, love."

On one side we are confronted by massive mining drills, on another we are met with an array of electric motors, used for the purpose of transmitting the subtle forces of electricity into the grosser forms of mechanical energy. A switchboard, or apparatus, for the interchange of circuits controls these motors, and is placed in the centre of the shop, so that the power may be directed to any given point. The presiding genii of this section are grim to behold, caked in smut and dirt, and powdered with shining filaments of iron and steel, but they are beneficent genii for all that, and favor us as we pass with a display of ivories, rendered peculiarly effective by its swarthy encasement. In the dynamo room are displayed various types of the electrical generators, sources of the current employed in the illumination of Mr. Edison's laboratory and house. The motive power for the laboratory machinery is furnished by a Brown engine of sixty horse-power, and the dynamos are impelled by Armington and Simms engines. Babcock and Wilcox boilers are employed aggregating two hundred and twenty-five horse-power. A feature of this establishment is the prevalence of magnetism, which is so potent that we are requested to remove our watches before entering the charmed precincts.

An elevator brings us to the second floor, from which we step into the "Precision department," embracing the lighter and more delicate minutiæ of machines, used in the construction of the phonograph vibrating diaphragm, with its fairy-like sapphire needle and



THE MAIN MACHINE SHOP.

the kinetoscopic apparatus. As may be imagined, the skill employed in this department is of a superior grade and commands a very much higher rate of remuneration. Very attractive is the glass blowing room, located on the same floor, and devoted to the construction of the experimental lamps. We spend a few moments watching the deft manipulation of the operator as he wields the plastic crystal, molding the fairy spheres and sending out clusters of shining threads. Adjoining this department is the mercury vacuum pump room, where the delicate globes are exhausted of air after the insertion of the carbon filaments. On this floor may also be found the series of rooms devoted to the development of ideas suggested in rude sketches, prepared by the inventor, and many interesting studies may be gleaned among the types represented by these skilled and intellectual members of the staff. Interwoven with the maturing of these suggestive thoughts is the process of "bug hunting," which is carried out with an ardor which allows no disorderly element to escape. Perhaps it may be as well to explain here, for the benefit of those unacquainted with laboratory terms, that "bug hunting" does not necessarily mean an entomological expedition, but the discovery and elimination of defects in connection with inventions in process of completion.

An interesting sight is afforded by the lamp test room, located on the top floor, and devoted to the accommodation of lamps in process of surveillance, the object being to determine efficiency and lasting power of each light, with a view to eliminating every conceivable defect before it is placed in the market. To this end a ceaseless watch is maintained, and a minute biographical record compiled, relative to each individual lamp, the whole constituting what is known as a "life test." Nothing more brilliant and beautiful

can be imagined than this aggregation of shining bulbs, suggesting stellar and planetary combinations foreign to our astronomical experience. We seem in presence of

"Larger constellations burning, mellow moons and happy skies."

But we should be in evil case, were our heavenly system subject to the disturbances which invade these sublunary spheres. Even as we stand, gazing admiringly at the golden radiance, a shiver runs through the clustered lights, a delicate crepitation, a silvery clang, and we are powdered with shining fragments, a catastrophe which brings to mind, in a mimic way, the pleasing wind-up of terrestial affairs portrayed in Monsieur Flammarion's latest cosmic nightmare.

A portion of the establishment most worthy of Edisonian students is the hall devoted to the exhibition of the inventor's creations. Prior to the exodus and disruption of 1889, these were arranged in complete order and in chronological sequence, but the Paris Exhibition occasioned the removal of many of these machines, and the collection has never regained its pristine completeness. Many of the inventions are still slumbering in the inglorious seclusion of their respective sarcophagi, and those which have escaped entombment have been sacrificed to Mr. Edison's careless disregard for fame. Whenever it seems good to this Tantalus of Science, his scientific progeny are coolly dismembered to form new feasts of reason, a fate which has befallen so many of the machines that the show cases, once devoted to their symmetrical entirety, now enclose nothing but mangled remains. Of course, as in the case of Pelops and Aeson, the elements of resuscitation are within, and may be built up on the original plan, but in the meantime the disintegration is somewhat painful to contemplate.

THE DYNAMO ROOM.

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EDISON EXPERIMENTING WITH MICROGRAPHY, IN THE ORANGE LABORATORY.

On our way to the lower regions, we pass the lecture hall, formerly in use for musical experiments in connection with the phonograph. If the nymph Echo and her coy attendants could be placed "en evidence," what tales could they not tell of the harmonies to which they have lent an antiphonal chorus?

The outbuildings now engage our attention. The chemical room is a favorite of Edison, and here he often may be tound, draped in an unsightly toga, the groundwork of which may once have been brown, but which is now embellished with strange devices in magenta, arsenic-green and yellow, the result of divers chemical catastrophes. He seems to be inhaling the evil smells with a gusto, undiminished since the days when he blew up his establishment on the Port Huron cars. Let us hope that the charmed life which he has borne in the past will extend far into the future, and that Orange may not be afforded the thrilling spectacle of a disintegrated inventor taking an involuntary flight over his own chimneys.

THE CHEMICAL ROOM.

The buildings devoted to photographic work, including the kinetoscopic experiments, are amongst the first things that meet the visitor's eye on approaching the grounds. The main photographic building is divided into the following compartments. In the general work room, which is covered with sliding glass skylight and side windows, a number of cameras of different sizes, equipped with fine lenses, are idly waiting their turn to be focussed on some new object. Science and nature are so happily united that no diurnal variations are permitted to impede the development of a subject, and unfinished work is completed at night by the aid of a large group of arc lamps, giving out fifteen thousand candle-power, supplemented by several calcium light appliances. At one side of the room may be seen one of the celebrated Zeiss

micro-photographic outfits, which has been of inestimable service during the many Edison lamp suits, in magnifying, to an extraordinary degree, the sectional views of the fibro-vascular bundles used in the manufacture of the carbon filament. Many micro-photographs have also been made by the aid of this valuable apparatus in connection with Mr. Edison's bacterial researches. The processes of silvering, printing, mounting, retouching and burnishing are carried on in this department, and the work bench and lathe, which occupy one corner, are in constant demand for kinetoscopic and kinetographic experiments.

The rooms above are devoted to copying and enlarging, as well as to the experiments in lantern projection. Around this room are stacked over a thousand negatives, which are being constantly added to, and many of which are used to illustrate this work. The dark rooms are arranged in consecutive order, are well ventilated, heated by steam in the winter and lighted by incandescent lamps, enclosed in ruby glass compartments and softened at will by lowering the candle-power. These dark rooms greatly resemble huge ice boxes as to construction, the walls being filled in with sawdust to keep the temperature cool in summer. It is here that the kinetoscopic films are treated, and during their many manipulations the operators are at times forced to work in Egyptian darkness, owing to the extreme sensitiveness of the film, which necessitates total exclusion of light, even to the extinction of the ruby glow.

A cursory reference has already been made to the kinetoscope and kinetograph, which were born amid these mysterious surroundings, and it may be well, before seeking new fields of thought, to bestow a few words upon these latest marvels of the laboratory. The terms kinetoscope and kinetograph are readily confused by the uninitiated, and it is well to explain, in this connection, that the former term applies only to the animated but soundless image. The kinetograph, on the other hand, is an instrument intended to reproduce motion and sound simultaneously, being a combination of a specially constructed camera and phonograph. The camera used in connection with this instrument will take forty-six pictures a second, corresponding to 2760 pictures a minute, or 165,600 in an hour. The rapid photographing of these pictures upon a long band of extremely light, sensitive film, creates the illusory spectacle of real motion of the figures, and when, to this visual impression, the phonograph is called to join its voice, we have a combination of effects upon both auditory and optic nerves. This specially constructed camera is attached electrically to a phonograph, and their combined movements are simultaneously registered, and thus we have the duplex sensation of vision and sound.

It will be seen that the above principles are based upon the familiar toy known as the zoetrope or wheel of life. This rude prototype contains a cylinder ten inches in width and open at the top, around the lower half of whose interior a series of pictures is placed, representing any sequence of motion it may be desired to portray, such for instance as wrestling, jumping or the swift progress of animals. These movements are seen through the narrow vertical slits in the cylinder during rapid revolution of the little machine, and are designed to blend into one continuous impression. In the zeotrope, however, the pictures are wood cuts of rude execution, and the limited speed attainable in the production of these militate against the lifelike effect, producing a series of jerks instead of the desired continuity of motion. When instantaneous photography, as evolved by Maddox and others, was brought into play, superior results were attained, but it seemed impossible to take pictures at sufficiently short intervals to secure the absolute blending of outline essential to a faithful portrayal of life. Matters were in this unsatisfactory condition when Mr. Edison laid hold of the problem, and succeeded in evolving a machine capable of producing photo-

THE PATTERN AND CARPENTER SHOP.

graphs on a narrow continuous strip at such inappreciable intervals as to secure absolute continuity, after which, by dint of exhaustive experiments, a synchronous electrical attachment was established with the phonograph, the dual contrivance being baptized by the name of kinetograph.

Opposite the photograph rooms is a curious looking structure of an irregular form, covered with tar paper and profusely studded with brass nails. The interior is as weird as the exterior and presents a contrast of lights and shades such as would have delighted the soul of Rembrandt. A platform occupies one end of the room, the rear of which is steeped in Stygian darkness, enhanced

by sombre drapery, while the foreground is bathed in a flood of light. As we peer into the illusive depths we seem transported to one of those cheerful banquetting halls of old, where the feudal chief made merry with human terrors, draping the walls with portentous black, and thoughtfully providing a set of coffins for the accommodation of his guests. And what is this mysterious recess at the other extremity, sharply outlined against the dazzling radiance of the middle ground and steeped in an angry crimson hue? Are these inquisitorial dungeons, and is that lurid glare the advance guard of the awful question? Is that gentle persuasive in process of administration, and do these half-guessed recesses conceal the hellish paraphernalia of rack and screw, glowing iron and crushing stone? Has the doom of ages overtaken our wizard at last, and is he expiating with twisted limb and scorching flesh, the treasures of his unlawful wisdom? Ah! me, that the prosaic truth must be told! No dungeons are these, thrilling with awful possibilities, but simply a building for the better "taking" of kinetoscopic subjects. On the platform stand the wrestlers, pantomimists, dancers and jugglers, whose motions it is destined to immortalize. Against the nether gloom their figures stand out with a sharp contrast of alabaster, basso-relievos on an ebony ground, furnishing a satisfactory explanation for the singular distinctness of the kinetoscopic strips. The lurid cell, at the other end, revolves itself into a compartment for changing the films from the dark box to the kinetoscopic camera, the apparatus being run backward over a track leading from the black tunnel at the rear of the stage to this room, after which the door is shut and the films renewed for a fresh subject.

We have been sensible for some time of a disturbance in the ground beneath our feet, and are now aware that the building is slowly and noiselessly rotating on an axis, bringing into our range of vision the glory of the sun rays westering to their close. Again we are reminded of that indissoluble chain of ideas which links the past with the present, and into the commonplace of existing facts come memories of that chamber in the golden house of Nero, so arranged that "by means of skillfully planned machinery it moved on its axis, thus following the motion of the heavens, so that the sun did not appear to change in position, but only to descend and ascend perpendicularly."

(To be continued.)

APPLIED MATHEMATICS AS AN EDUCATIONAL FACTOR.

By F. R. Hutton, C. E., Ph.D.

ONE of the topics for discussion presented at the International Congress of Education, which was held at Chicago last July, was "The Educational Value of Applied Mathematics, Including Engineering," and the writer had been requested by the committee of the Department Congress of Technological Instruction to prepare a brief paper on the subject in order to open the debate.

In complying with this request the writer assumed at the outset that the important work of the lower and preparatory schools—the fitting of the student for his technical course of training—is well done. There would then appear to lie behind the course of instruction in the technical schools two fundamental starting points. The first of these is that which has for its object the familiarizing of the student with those principles of pure science and knowledge which the engineering student must have as the foundation of all his later work. If we receive that definition of engineering, which represents it as aiming to bring to humanity for the progress of civilization the utilization of those laws and forces which have been provided by a wise and loving Creator for the progress of the race onward and upward, then it is impossible to lay too much stress upon this solid groundwork of scientific principles and laws. These principles, in themselves, are valuable as means of education, when they are derived either by deduction from accepted axioms, or from foundation principles intuitively apprehended, as well as by induction from the observation of phenomena.

The educational value of this class of instruction is even most considerable in the domains of mathematics and what is called natural science. In these we get that mental training which comes from deduction and induction in their most rigid and exacting forms. After a certain point, however, it becomes rarely possible to take the time to compel each student to convince himself of the existence of a particular law or principle, and the instruction takes the form of the predication of law and principle by authority, and the familiarity of the student with the law becomes a question of his exact memory of what he has read or heard. While it is of course helpful and convincing to know that a certain theorem is accepted as true, because it has been proved to be so by some one whom the student respects, yet is it not possible for a man with a good memory to pass successfully through the requirements of this part of his course in a condition of mental Nirvana, where he is satisfied with the exalted plane of achievement in the text-book or lecture-room atmosphere, while the other faculties of his mind, which education must bring out and strengthen, lie comfortably and lazily undisturbed by any exaction for their use so far as the course of study is concerned?

The second starting point in technical instruction is that from which the paths lead to the application of these scientific principles and natural laws to the problems of civilization and industry as they come to the engineer. This is instruction in applied mathematics, applied physics or applied chemistry, as distinguished from the study of these as pure sciences, and is an instruction which is deemed of paramount importance. It begins perhaps at the middle of the school life of the student, but it ends only with the end of his natural or active life.

It forms that part of a man's educa-

tion which is never completed. It is difference in ability to apply successfully his knowledge of principles in the conduct of practical affairs which differentiates the successful practitioner of engineering from him who is professionally but a cumberer of the ground, for whom no one has any use.

This instruction in applied science or engineering will, of necessity, be given along two lines. Every formula of practical value must have its theoretical expression, which is deduced *a priori*, modified by co-efficients of experience and practice, which shall take account of variable conditions or factors which the exact theoretical formula cannot, from the nature of the case, embrace. The two lines of instruction in this field will therefore involve, first, descriptive and explanatory instruction, which shall discuss these conditions of service, shall record successful achievement, and shall present and explain empirical formulæ.

The second line, based somewhat on the first, but having its own special peculiarities, must aim at a broad and far-reaching training, which shall make a man competent, not only to repeat the achievement of a pioneer, but competent to predict on the basis of past performance what will be the action and result of new combinations in advance of experience. It is a man with this latter capacity who is the engineer.

There is no question that this second division is the most important. The first division is most admirably provided for by the Engineer's Pocket-books and Hand-books of formulæ, but we are unwilling at this date to say that a knowledge of pure science and a shelf full of hand-books will make an engineer. We have a safe and conservative plodder and subordinate, but we have not a man of resources, nor have we the best man that could be made.

Permit the digression to say that by the foregoing it is not intended to undervalue the Pocket-book. Engineering students should be taught to use them wisely and accurately as a part of their school training in the drawing room. But exactly as his knowledge of the use of the slide rule cannot be permitted to take the place of drill in the use of logarithms, so the hand-book cannot be used exclusively to the exclusion of individual responsibility and thought, without a tendency, narrowing and belittling its character, so far as the man himself is concerned.

The claim is therefore broadly made that applied mathematics, including engineering, is as efficient a means of educating a man as any study of the curriculum, and the reason for this is that the study of engineering gives a scope and an occasion for the development of the reasoning powers, of the critical faculty, and of the power of intelligent and wise choice. It is further claimed that the development of these powers will result in a stronger man, a more reliable and firm character and a broader grasp of the significance of professional opportunity.

It has been conceded that a fundamental defect attaching to the study of languages, either classic or modern, is their tendency to over-train the memory for verbal forms and syntactical peculiarities at the expense of those mental capacities of judgment, criticism, or selection, which have most to do with the affairs of every-day life. It is this which lies at the bottom of satire upon the helplessness of merely literary professors and others, and which has again given sting to the valuelessness of a scholar's training as it used to be, as a fitting school for technical affairs and business. If our principle is right it explains why, under a system of marks, the man who ranked first in a class graded upon ability to cope with the intricacies of grammar should rarely have been as successful in winning reputation as some less conspicuous wight further down the roll. The valedictorian had an excellent verbal memory and an extensive vocabulary. Down the class, however, were those who had more reluctance to yield themselves to the guidance of recorded rule, and yet had in compensation the faculty of perception, wise deduction, and even of origination. In engineering, when properly taught, from the very fact that

it is not an exact science, like the pure mathematics, there is an opportunity given to bring out this most important principle of critical choice or selection of method which underlies that successful mastery over circumstances, which means success and reputation, and that which these two bring, if other things are equal.

To a pure mathematical problem there is either no solution, the solution is indeterminate, or there is a fixed number of solutions. In engineering this is not so. He is easily discouraged who says there is no solution to a problem in engineering. The whole history of this century repeats over and over again the solution of that which was formerly said to be impossible even by high authority. In engineering the problem cannot be indeterminate when its solution, as in a manufactured article or in an achievement, is presented in a concrete form.

It is a most important consideration of any which can be impressed upon a young man, that in engineering problems there are many practicable solutions to every one, and (here mark the essential kernel of the whole matter) that it is left for him to make the choice of the most suitable solution under the special circumstances in which that particular problem comes to him. It is this exercise of a trained, critical or judicial faculty, called by whatever name —common sense, horse sense, shrewdness, acumen, or what not—which engineering, more than any of the other professions, medicine alone, perhaps, excepted, demands from its successful representatives.

It is to be noted further that the considerations which are to be guiding factors in the exercise of this judgment, or critical faculty, or common sense, are not to be found in the school textbooks, nor in the pocket-books usually, nor from an authority calling down the vista of even an honored past. The choice has to be guided from the conditions of the day and the hour. The achievement of to-morrow must be built upon the success of to-day, the discovery of the last new combination, and even the commercial environment of the district where the solution is to be realized. It, therefore, comes back upon the teacher of engineering so to shape his instruction in this field that the men under his instruction shall be able to make the most of themselves, he standing by to help all in his power.

How shall this be done?

First. Teachers of engineering art should be engineers possessing this element of sense, judgment and critical faculty, rather than scientists only—who may be competent authorities in pure science, but nothing more.

Second. Teachers of engineering should be practitioners in touch with the competition of the day, familiar with achievement of colleagues and rivals, and with their critical and judicial faculty cultivated and in active use. They should be able to exhibit the action of the trained mind before the student, and not merely to theorize about its action. They should not be compelled to follow too far behind the lead of those who are at the head of their specialty. This is the great difficulty connected with the promotion to responsible professorships of young men who are put into subordinate positions in the schools immediately upon graduation without an opportunity for contact with the competitive conditions of professional practice.

Third. Teachers of engineering should have some capacity as administrators and business men. Here at once a difficulty is presented. A comparatively small number of our professors can be the executive head of their institution, although American technical education exhibits notable instances of success along these lines.

On the other hand, business exigency demands that the head of a corporation or firm shall give his entire time to its business, which the professor of engineering is of course debarred from doing.

The most practical solution of this difficulty has been reached where it has been possible for the teacher of engineering to have his work supplemented by lectures, isolated or in course, by

successful practitioners, who have made a name for themselves in their specialty. This procedure is not without its difficulties and drawbacks in spite of its obvious advantages. The advantages are, the contact between student and practitioner, which is stimulating to the former in the highest degree, and he feels sure that the point of view of the lecturer is that of the competitive conditions of the day. The disadvantages are, the danger lest these very competitive conditions prevent the lecturer from giving due recognition to the excellence of rival achievements. There is the further danger of disagreement between the lecturer and the regular professor, while both may be right. The student is likely to suspect errancy on the part of him who disagrees with a specialist, and the taint of errancy in one department may extend to seriously affect the efficiency of the regular instructor in all departments. There is the further difficulty that the lecturer may pass over the heads of his auditors, and the difficulty of finding time in a crowded course for much of this sort of additional work.

It would take us too far afield to pursue this discussion in detail, but it is the opinion of the writer that the advantages overweigh the disadvantages, and that instruction by such lecturers is desirable when practicable.

Fourth. So far as the student himself is concerned, his fundamental training in science should begin back in the preparatory schools, so that the latter part of the curriculum in the professional school can be specially devoted to this advanced training of the man and the strengthening of his faculties by devotion to the applications of law and principle, and the strengthening of the mental powers in this direction,

Fifth. There should be symmetrical culture of the body, both muscle and skill, and perceptive capacity, no less than training of the mind. How capable soever the mind may be as a tool, the handle by which it is directed by the will must yet remain the body and its ability to carry out the directions which the intelligence gives.

Finally, and in a word, if it be the object of education to lead out and develop the God-given capacities of a man, to give him a kit of sharpened tools and a trained capacity to use them, to make him more the master of unfriendly environment, to make him more capable of lending a hand to help upward those about him less favored than he, to teach him the basis on which to decide between that which is wise and unwise, between right and wrong, then the contention of this paper is, that there is no training in education superior to engineering when properly carried out to produce self-reliant, independent, creative thinkers, —to produce God-like men.

IMPROVEMENTS IN ELECTRIC CABLE MAKING.*

By Emil Guilleaume.

THE art of cable-making has received an increased impulse during these last ten years, from the wonderfully extended application of electricity for telegraphic and telephonic service, for electric lighting and transmission of power, as well as from the growing necessity of placing the leads underground. The numerous patents which have been and which still are applied for, are the best proof of the attention given to this art. It would be going too far to discuss all the inventions which refer to improvements in cable making; for the most part they are of very little, if any, practical importance, and of the few which have stood the practical test, only a small percentage may claim the character of a striking novelty.

The term "electrical cable" ought, strictly speaking, only to apply to an electrical conductor insulated and dressed or sheathed in such a manner as to have the appearance of a rope or cable and to coil like one; lately, however, this term has been extended to include insulated rods and tubes, such as the well-known Ferranti cable. Every cable for the conveyance of electricity is composed of the cable-core (one or more insulated conductors) and the protecting armor or sheathing.

The cable-core is composed of the conductor (leading wire) and the insulating covering. The conductor may be formed of a single wire, or of a number of wires formed into a strand or rope. The wire or wires may be of circular, or of any other section; as a rule, it will be made of copper of high conductivity, and only in exceptional cases, where, besides conductivity, a more or less high tensile strength is claimed, copper compounds (alloys) and steel are made use of. Important progress has been made in the manufacture of copper wire of almost absolute pureness and accordingly high conductivity. Whereas formerly one had to be content with copper wire with a conductivity of ninety per cent. of that of pure copper, we have now copper wire at our disposal which yields more than 100 per cent.; *i. e.*, purer than the copper Matthiessen considered to be pure copper, when he took it as his standard for determining the pureness and conductivity of copper leading wires.

Other notable novelties respecting the conductor are confined to the shape or section of the wire. Thus, Messrs. Felten & Guilleaume of Mulheim-on-the Rhine, Germany, have been granted patents for telephone cables of low capacity, in which the leading wires of the core are of a triangular, rectangular, or star-shaped section. The wire is twisted round its own axis, and the spiral grooves thus formed on the surface of the wire allow the insulating material to touch only the top edges of the grooves, the latter themselves forming air-spaces between the insulating material and the spirally wound sides of the wire. Messrs. Felten & Guilleaume also manufacture electric light cables in which the conductor is composed not of round wires but of wires of segmental section, in order to do away

*Presented at the International Engineering Congress at Chicago.

with the empty spaces between the wires, and thus materially reduce the diameter of the core as well as the diameter, weight and price of the cable. Others have for the same purpose proposed to deform the leading wire longitudinally, *i. e.*, instead of using straight wire, to corrugate it or bend it into a zigzag; such proposals, however, can hardly be seriously considered.

The insulation or insulating material is the vital part of any cable, and yields the most fertile working field for the ingenuity of cable engineers. The claims on the properties of the insulating material are so manifold that it is often very difficult to combine them in one material. According to the use of the cable, whether for telegraphic or telephonic service, for electric lighting or transmission of power, more or less high claims are put on the insulating material as to the insulation resistance, the absence of static capacity, the prevention or reduction of the disturbing influence of induced currents, and the tension resistance. The insulating material must preserve the claimed properties for as long a space of time as possible; it must not soften under the influence of heat; it must not get brittle under the influence of cold; it must at all times and in any position of the cable retain the conductor in its central position in the core; it must, further, possess a given tensile strength, and sufficient power of resistance against external pressure; size and weight may be of importance, and must be taken into consideration; also the price.

At the early stages of cable-making, when cables were without exception wanted only for telegraphic service, gutta percha and india rubber were used exclusively, and gutta percha continues to be the chief insulating material for submarine cables. The good properties of both are sufficiently known; however, with cables that are exposed to heat, and with electric light cables, in which the conductor is apt to increase in temperature, one has to reckon with the drawback that gutta percha is softened by heat, and that then the leading wire will sag out of its central position. Vulcanized india rubber is less influenced by heat, but it is very costly, and the high price is the reason why gutta percha and india rubber are only used to a limited extent, in particular for electric light cables with larger sections of copper conductors. For use in buildings, smaller leads, etc., pure india rubber is also sometimes used with a serving of cotton or silk on the wire. Improvements in connection with gutta percha and india rubber have been principally carried out in the way of cleaning the raw material and in the covering machines; also in bringing out superior india rubber compounds and new methods of covering the wires. India rubber cores have usually two or three coverings of india rubber; where there are three, a layer of pure Para rubber is applied next to the wire, then a second layer, termed the "separator," without sulphur, and finally the "jacket," with an addition of sulphur. Such cores, varying in composition and with different rubber compounds, are known in the trade as "hoopers," okone-, kerite-, neptunite-cores, and by several other names.

The high price of gutta percha and india rubber compelled cable engineers to look for substitutes which might be had in any desired quantity at a reasonable price, and possessing the qualifications for the various purposes of application; viz., low capacity for telephonic purposes, and sufficient strength to withstand the effects of heat and high tension for electric light purposes. Numberless are the inventions made and the patents claimed in this direction. All of these deal with specially prepared mineral and vegetable oils, bitumen, resin, wax, or mixtures of one or more of these with other, preferably carbonaceous, substances. All of them are, however, more or less poor substitutes for gutta percha or india rubber; they do not possess the valuable, tough elasticity, they either soften under the influence of warmth or get brittle under the influence of cold, or they shrink in time and crack. The first great step forward in this direction was the employment of fibrous material in connec-

tion with the above substances, the wire being served with a winding or braiding of thread, or a wrapper of tape and finally of paper, this serving being impregnated with one or the other or with mixtures of the aforesaid substances. The serving of thread, tape, or paper retains the wire in its central position in the core, and the impregnation of the serving with oil, resin, wax, etc., or their compounds, yields the desired insulation resistance. In some cases the impregnation may be dispensed with, as the dry fibrous material offers in itself a certain insulation resistance which may be found quite sufficient for the case being. By this means, the object of having cheap and yet efficiently insulated cable conductors has been attained.

As all fibrous insulation is more or less hygroscopic, it is necessary to prevent any access of moisture. This is done by encasing such cores in a lead pipe, forming them into so-called lead cables with impregnated or non-impregnated fibre or paper insulation, as almost every large cable-works manufacture them now with more or less success in one or another composition.

With the ever increasing importance of telephonic communication and with the growing want of being able to speak at greater distances through cables, it became necessary to pay particular attention to the capacity of the cable-cores, as it was found that certain difficulties which were met with when trying to speak through a cable at great distance were caused by too high a capacity. The injurious influence of static capacity is already experienced on comparatively short telephone cable lines, inasmuch as the transmitted sounds are much more weakened than in passing through aerial lines; indeed, the result was such that at first it was given up as a hopeless case to use cables for long distances. Cable-makers were thus put to the task of inventing telephone cables in which the static capacity was to be reduced to a minimum, *i. e.*, in which the conducting wire is covered with an insulating material which, as regards static capacity, would yield the most favorable results. Atmospheric air gives, as is well known, the best result; next comes paper, then paraffine (twice the capacity of air), cotton, silk, india rubber, gutta percha and glass (from six to ten times the capacity of air). A cable in which the conductors are surrounded by air would, therefore, give the best results as far as static capacity is concerned; but as the conductor cannot be kept central without a support of some sort or other, the best cable would be such in which the conductor was kept central in a pipe filled with air by the aid of the least voluminous supports, the latter composed of a material of the lowest possible static capacity, or in which the conductor itself was of such a form as to touch the insulating shell with the least possible portion of its surface. Of this latter alternative I have spoken before as a reason for using either twisted wire of a triangular, rectangular, or star-shaped section, or corrugated or zigzag wire.

The other alternative has been tried in various ways, viz., *a.* By filing beads of wood or ebonite or glass on the conducting wire; *b.* By winding a line of thread or cord around the conductor in an open spiral so as to leave plenty of air-space between the windings; *c.* By serving the conductor with an open braiding of cotton thread, or cord; *d.* By interbraiding the several conductors with cotton thread, thus keeping them separate from one another by the thread and forming air-spaces between them; *e.* By providing air-spaces in the insulating material (mostly paper tape) by curling or frilling or perforating or embossing the same; *f.* By twisting a strip of non-conducting material about its own axis to form grooves or air channels in which the conductors lie.

This last named way of solving the problem is an invention of Messrs. Felten & Guilleaume, whose patent lead cable, with paper insulation and air-spaces, has given the best results, the static capacity being reduced to 0.06 microfarad per statute mile at a temperature of sixty degrees Fahrenheit, whereas with other cables of the same pro-

portions the capacity would be 0.48 microfarad with india rubber, 0.16 microfarad with fibre insulation, and 0.08 (lowest) with the ordinary paper insulated cables. Thus one can speak through a cable with paper and air insulation over a correspondingly longer distance with the same clearness of sound. This arrangement at the same time allows of the smallest diameter of the cable, and each core is easy to trace.

Another important factor in judging of the value of a telephone cable is the absence of induction, the presence of which is the cause of the most annoying cross-talk. The best and safest way of overcoming this difficulty will be the introduction of metallic circuits, *i. e.*, to do away with earth connection and provide two cores in the cable for each subscriber. However, this for one reason or another cannot be done in all cases, and where only single conductor cables can be used, provisions will have to be made to reduce the disturbing influence of induced currents to a minimum. This problem has been more or less perfectly solved in different ways, viz.:

a. It has been proposed to cross the cores at given intervals in the cable or in the cable joints, similar to what is done on aerial lines for the same purpose. This complicates the manufacture of the cables materially and attains the desired object but imperfectly.

b. Another way of making the cores cross one another at as near as possible a right angle has been proposed by twisting two cores together in very short windings.

c. The same leading thought has been instrumental in the invention of the solenoid (Lugo) cables, in which a portion of the cores are wrapped round the others.

d. The most effectual way of doing away with the annoying influence of induced currents is a wrapper of tin-foil around each core and the provision of one or more earth copper wires between the cores.

The wrappers of tin-foil collect the induced currents, and, as they are in metallic connection with one another and with the earth wires, the latter need only be connected to earth in order to remove the induced currents. It must not be overlooked, though, that the wrapper of tin-foil increases the static capacity.

Worth mentioning is the twenty-eight-core telephone cable adopted by the German postal authorities. This cable can be used as a single conductor as well as for metallic circuit. To that end the twenty-eight cores are arranged in seven groups, each of four cores. The conducting wires are insulated with impregnated fibre, and each core has a serving of tin-foil. The four cores of a group are stranded around a non-insulated copper earth wire. These cables have given excellent results, and Messrs. Felten & Guilleaume, have recently constructed telephone cables on the same principle with their patent paper and air insulation, a thin copper strip being inserted in the cross-shaped paper stay to collect the induced currents and lead them off to earth.

The safest way of preventing any annoyance by induced currents is, as said before, the application of metallic circuits; *i. e.*, to provide two lines in the cable for each subscriber. It has hitherto not been possible to more generally adopt metallic circuits on account of the cables becoming more voluminous and more expensive. With Felten & Guilleaume's patent paper air-space cable, however, this difficulty is to a great extent removed; their metallic circuit cables are very compact and neither much more voluminous nor much more expensive than the former single conductor cables, at the same time combining the lowest static capacity with an almost total absence of induction.

The splicing of these cables is very simple and can be accomplished by any jointer accustomed to jointing paper cables, the operation being almost the same.

Paper cables with air insulation are with equal advantage applicable to telegraphic service, only that all the dimensions of the conducting wire, cores

and cable will be comparatively enlarged. The diminution of static capacity not only prevents or, at any rate, lessens the transfer from one conductor to another—which so often is the cause of disturbances—but it also increases the speed of transmission or, at equal speed, the distance may be extended, thereby rendering the line more remunerative.

Cable manufacturers have been put to a perfectly novel task by the rapid development of electric lighting and electric transmission of power with the aid of currents of high tension. Here they had to deal with claims on the cable which were very different from those on telegraph and telephone cables. Static capacity, except with concentric and biconcentric cables, is of less importance than the avoidance of danger arising from the insulation (in consequence of the heating of the conductor) being impaired or pierced by the high tension currents.

Impregnated fibre and paper are largely used for electric light cables, especially since the introduction of alternate currents of more and more high tension. In this construction the insulating material must combine a great solidity with toughness and elasticity, qualities which no other materials possess in as high a degree.

The choice of the paper to be employed is a delicate matter. In consequence of the great variety of paper produced, it is necessary to exercise particular care when selecting paper for insulating purposes. The paper must have a low capacity and at the same time insulate well; it must also possess sufficient strength to stand the strain of the machines in covering the wires. A covering of paper in comparatively thin layers will do the needful; therefore, paper insulation insures the smallest diameter of cable as well as a minimum weight and price.

With gutta percha and india rubber cables the armor or sheathing is intended chiefly to protect the cable core against mechanical injury. Submarine telegraph cables are sheathed with round galvanized iron wire. For deep sea cables it is important that the size of the sheathing wires be reduced as much as possible while retaining a high tensile strength, and improvements in this direction have been made in the way of producing galvanized steel wire of very high breaking strain per square inch of sectional area.

Until the last year or two No. 13 gauge wire, with a breaking strain of about sixty tons per square inch, has been employed for this purpose, but at the present time No. 14 gauge wire, with upward of eighty-five tons per square inch, is in use, and even No. 15 gauge wire finds employment.

The wires are served with a special compound as a better protection against the injurious effect of sea water. The ravages of the teredo and other insects on gutta percha cables have been successfully done away with by lapping the core with brass strip.

With fibre and paper cables it is of utmost importance that the sheathing absolutely prevents the access of moisture. Therefore, these latter cables are invariably sheathed with lead, and the improvements which have been proposed in lead sheathing chiefly tend to having perfectly water-tight sheathing which will retain its water-tightness however badly the lead cable is handled.

As a protection against mechanical or chemical injury, a small percentage of tin is sometimes mixed with the lead, usually three per cent.; also in some cases a second lead sheathing is put on with an intermediate layer of compound between the two sheathings. Gutta percha and india rubber cables are sheathed with lead only when they are used as leading-in wires and at stations.

Where the diameter and a smooth surface of the cable is of consideration, flat wires are used instead of round ones, as supplied to the German postal authorities, or the cables are sheathed with iron or steel strips. Underground lead cables for telegraphic and telephonic service are sometimes protected by a sheathing of galvanized iron wires over the lead, and where it is desirous that the cable should have a smooth surface and the smallest possible diame-

ter, flat-shaped galvanized sheathing wire is employed.

Messrs. Felten & Guilleaume have also introduced, as a novelty, patent locked wire sheathing in connection with their submarine telephone cables with air-spaces. Such sheathing will keep off any strain or pressure from the core, which is, so to say, enclosed in a non-compressible tube. Electric light lead cables are often sheathed with galvanized wires, and, in preference to other kinds of sheathing, with iron strip, which, if embedded in compound and with an external hemp serving, affords a most effectual protection.

A COAL CALORIMETER.*

By Geo. H. Barrus, Mem. Am. Soc. M. E.

IN view of the increasing prominence given to the determination of the quality of coal, it seems desirable to record some of the results which have been obtained by the use of one form of instrument designed and operated by the writer. The instrument has been employed for the past three years, and during that time samples of nearly one hundred different coals have been subjected to the calorimeter test. No definite line of investigation has been undertaken to determine the heat of combustion of selected varieties of coal. The tests have been made on coal which has been used on evaporative trials of boilers which the writer has conducted, and on samples which have been submitted to him from time to time by clients who wished the value of the coal obtained. A large share of the fuels are coals mined in Maryland, Virginia and Eastern Pennsylvania. Few coals from points in the United States farther west have been tried.

The complete apparatus consists of the calorimeter proper, of small scales used for weighing the water used in making the determinations, chemical scales for weighing the coal and ash, which latter scales are sensitive to a fraction of the milligramme, and an oxygen tank for supplying oxygen gas for combustion of the coal samples. The calorimeter itself consists of a glass vessel five inches in diameter, nine and one-half inches high, which holds the water of the calorimeter. Submerged in the interior is a bell-shaped glass vessel two and one-half inches in diameter, 4 inches high having a long neck three-quarter inch in diameter, which is closed at the top with a stopper. The upper end of the neck stands five inches above the top of the outside vessel. The glass bell, or "combustion chamber," as it may be termed, rests upon a metal base, to which it is held by means of spring clips, the bottom of the chamber being provided with an exterior rib by means of which the clips are made fast. The base is perforated, and at the centre is mounted a short tube, for the reception of a crucible, in which the combustion takes place. The crucible is made of platinum. It is surrounded by a layer of non-conducting material, which is placed between it and the outer metal. A small glass tube is inserted in the stopper at the top of the neck, and this is carried down to the interior of the combustion chamber. It is fitted somewhat loosely, so that a slight pressure will move it up or down, and thereby adjust its lower

* From a paper presented at the International Engineering Congress at Chicago.

end to any height desired above the crucible. The tube has a slight lateral movement also, so that it may be directed, at the will of the operator, toward any part of the crucible. This tube is connected with a tank containing oxygen gas, and through it a current of gas is passed, so as to enable the combustion of the coal to be carried on under water. The pressure of the gas drives out the water which would otherwise fill the chamber, and keeps its level below the base. The products of combustion rising from the crucible pass downward through the perforations in the base, escaping around the edge of the base, and finally bubbling up through the water, and emerging at its surface. A wire screen is secured to the neck of the combustion chamber, extending to the sides of the outer vessel, thereby holding back the gas and preventing its immediate escape to the surface of the water.

In making the test, the quantity of water used is two kilogrammes or 2000 grammes, and the quantity of coal one gramme. The equivalent calorific value of the material of the instrument is 185 milligrammes. One degree rise of temperature of the water corresponds therefore to a total heat of combustion of 2185 B. T. U. The number of degrees rise of temperature for ordinary coals varies from five and one-half degrees to six and one-half degrees Fahrenheit. The thermometer used for determining the temperature of the water is graduated to twentieths of a degree, and as the divisions are about one-thirtieth of an inch apart, they may be subdivided by the eye so as to readily obtain a reading to hundredths of a degree.

The process of making a test is as follows: Having dried and pulverized the coal, and weighed out the desired quantities of coal and water, the combustion chamber is immersed in the water for a short time so as to make the temperature of the whole instrument uniform with that of the water. On its removal, the initial temperature of the water is observed, the top of the chamber lifted, the gas turned on, and the

RESULTS OF TESTS WITH THE BARRUS COAL CALORIMETER.*

Cumberland Coals.

Number for Reference.	Kind of Coal: Mine or Locality.	Percentage of Ash.	Total Heat of Combustion.
1	George's creek...........	6.1	14,217
2	"	6.6	13,925
3	"	8.6	12.874
4	"	6.5	12,921
5	"	7.	13,360
6	" (Am. Co.).	5.	13,487
7	" (Md.C.Co.)	5.1	13,656
8	" (G. C. Coal and Iron Co.)..........	5.7	13,424
9	George's creek..........	5.1	13,745
10	Eureka	5.1	13,653
11	"	5.4	13,427
12	George's creek..........	4.4	13,923

Miscellaneous Bituminous Coals.

Number for Reference.	Kind of Coal: Mine or Locality.	Percentage of Ash.	Total Heat of Combustion.
13	Pocahontas..............	6.2	13,608
14	"	4.	14,121
15	"	5.	14,114
16	"	6.5	13,697
17	"	3.2	14,603
18	Clearfield	4.7	13,640
19	"	11.1	12,517
20	New river................	0.6	14,273
21	"	1.	14,455
22	"	5.7	13,858
23	"	3.5	13,922
24	"	5.	13,858
25	"	4.1	13,922
26	Welsh (English)	7.7	13,581
27	Lancashire (English)......	6.8	12,122
28	Sonman..................	6.9	13,326
29	"	8.3	13,267
30	"	7.	13,210
31	Elenora..................	7.5	12,765
32	"	6.8	12,877
33	Eclipse..................	2.7	14,114
34	Elk Garden..............	7.8	13,180
35	Mix. New river and Cumb.	6.7	13.361
36	Frontenac (Kansas)......	17.7	10,506
37	Cape Breton (Caledonia)..	8.7	12.420
38	Youghiogheny, lump (Ac.)	5.9	12,941
39	" slack (Pac.)	10.2	11,664

Anthracite Coals.

Number for Reference.	Kind of Coal: Mine or Locality.	Percentage of Ash.	Total Heat of Combustion.
40	Honey Brook, Ches. No. 2.	12.	11,733
41	Cross Creek, "	10.5	11,521
42	Lackawana—Egg.........	17.5	11,104

*In this table only those coals referred to more specifically than by a number simply are given. There are, therefore, less specimens referred to here than in Mr. Barrus' original table, which comprised sixty-one tests.—THE EDITOR.

coal quickly lighted, a small paper fuse having previously been inserted in the crucible for this purpose. The top of the combustion chamber is quickly replaced, and the whole returned to its submerged position in the water. The combustion is carefully watched as the process goes on, and the current of oxygen is directed in such a way as to secure the desired rate and conditions for satisfactory combustion. When the coal is entirely consumed, the interior chamber is moved up and down in the water until the temperature of the whole has become uniform, and finally is withdrawn and the crucible removed. The final temperature of the water is then observed, and the weight of the resulting ash.

The initial temperature of the water is so fixed by suitably mixing warm and cold water that it stands at the same number of degrees below the temperature of the surrounding atmosphere (or approximately the same) as it is raised at the end of the process above the temperature of the air. In this way the effect of radiation from the apparatus is overcome, so that no provision in the matter of insulation is required, and no allowance needs to be made for its effect. The table on the preceding page presents a list of some of the tests which have been made with the instrument.

LEADING AMERICAN ENGINEERS.—E. D. LEAVITT.

PROBABLY few American engineers have so widely-established a reputation and are so generally well-known as Erasmus D. Leavitt, whose work in the line of high-class steam machinery has for years past furnished examples for admiration and instruction alike.

Born at Lowell, Mass., on October 27, 1836, he received his early education in the public schools of that city, being subsequently apprenticed to learn the trade of machinist to the Lowell Manufacturing Company. This apprenticeship extended from 1852 to 1855, and was followed by a year's work, under instructions, with Messrs. Corliss & Nightingale of Providence. For two years thereafter he was engaged in developing improvements in valves and valve gearing for steam engines, and in 1858 and 1859 became assistant foreman for Harrison Loring, at the City Point Works, at South Boston. After this he was promoted to the position of chief draughtsman for Thurston, Gardner & Co., of Providence, R. I., builders of the Greene engine, which position he resigned in August, 1861, to enter the U. S. Navy as third assistant engineer.

While thus in the naval service he was stationed on the gunboat Sagamore, in the Eastern Gulf Squadron, from September, 1861, until July, 1863, at which time he was promoted to the office of second assistant engineer, and subsequently engaged in construction duty at Baltimore, Boston and Brooklyn. Two years later he was attached to the Naval Academy at Annapolis, but resigned in 1867 to assume practice as a mechanical engineer, to which profession he has since devoted his life.

In 1873 he was elected a member ot the American Society of Civil Engineers, and in 1876 became a member of the American Institute of Mining Engineers. He was also one of the founders of the American Society of Mechanical Engineers, in which society he has served as manager, vice-president and president. Among other similar institutions of which he is a member are the Boston Society of Civil Engineers, the Franklin Institute of Philadelphia, the Institution of Civi Engineers and the Institution of Me-

chanical Engineers of Great Britain and the British Association. The honorary degree of Doctor of Engineering was conferred upon him several years ago by Stevens Institute of Technology.

Dr. Leavitt, in connection with his practice as a mechanical engineer, has organized what is doubtless the largest corps of draughtsmen to be found in this country, and while his specialties may be said to be pumping and mining machinery, examples of which are to be seen in various parts of the country, he is constantly being called upon to furnish designs for other kinds of machinery, and to examine, revise and test steam plants already in existence.

To Dr. Leavitt justly belongs the credit of being the first in this country to inaugurate a marked advance in the economic duty of pumping engines for supplying cities with water. While the recorded duty of his Lynn engine has been equaled in late years by other builders, it was at the time that it was designed and put in operation a remarkable advance on what had previously been accomplished in that line of engineering, and as an evidence of the skill displayed in planning it, and of the faithful manner in which it was built, it may be said that, after the many years of service which it has seen, its daily performed duty is still looked upon as being somewhat marvelous.

While the impress of Dr. Leavitt's genius and skill has been made manifest in various ways and in a variety of engineering constructions, his best work is to be seen in what he has accomplished as the consulting and designing engineer of the Calumet and Hecla Mining Company. Fortunately for him, and especially fortunately for that famous mining company, it would seem that by the combination thus formed the business affairs of what has since proved to be the most productive copper mine in the world was in the hands of a management who not only had faith in its future, but who also recognized the fact that in the end the economic results would be far more satisfactory by adopting at the beginning the use of the best machinery obtainable, rather than depending on temporary construction to be enlarged or supplemented, as the property was developed, and who, after coming to such a conclusion, turned over the problems pertaining to the engineering necessary to produce the best results to one whose fidelity to their interests, as subsequently shown, was equaled only by his untiring industry, skill and good judgment.

This is not the place to enter into a description of the engineering plant of the Calumet and Hecla Mining Company, situated in what was at one time the almost inaccessible peninsula of Michigan, and within the almost arctic regions of Lake Superior, or to discuss the many difficult questions that controlled the selection and construction of the various boilers, engines and other appliances required in mining and preparing for market the product of that region; and while engineers may, and ever will, differ as to the matters of detail in construction, there are no American engineers at all familiar with the situation, and with what has been accomplished under the direction of Dr. Leavitt, who do not point with just pride as an example of what an American engineer can design, and what American engineering works and workman can produce, to the splendid machines that throb and beat, turning immense wheels, pumping rivers of water, and stamping enormous piles of rock at the world-renowned mines of the Calumet and Hecla Company.

ERNEST V. CLEMENS.

ERNEST V. CLEMENS, whose death occurred in New York city on September 3, was born on April 3, 1855, at Waterbury, Conn. He came from good New England stock, and his lineage may be traced back to Colonial times, on his father's side to the Clemenses who settled in Stratford, Conn., before the Revolution, and on his mother's side to the Girards, among whose members was Stephen Girard, the founder of Girard College at Philadelphia. His father, who is still actively engaged in business at Ansonia, Conn., wished to have him study law, while his mother desired that he should enter the ministry. He became interested in mechanical matters, however, and as a boy was taken in the shops of the Farrell Foundry and Machine Company, of Ansonia, Conn., where his father was superintendent. It was there that he laid his foundation for success in the engineering field, for, after completing his apprenticeship, he worked as a pattern-maker, foundryman, machinist and draftsman. His first important work was the installation of a sugar plant on an estate in Cuba, for his life-long friend Santiago W. Melloro. After the completion of this work he was for a number of years superintendent of the National Machinery Company, of Tiffin, Ohio; of the Clemens Foundry and Machine Company, of Ansonia, Conn., and of the Farrell Foundry and Machine Company of the same city, and for the past five years was the general superintendent of the De La Vergne Refrigerating Machine Company. He was one of the leading spirits of this concern as well as of the White Cloud Copper Mining Company, of which corporation he was treasurer. The town of Clemens in Nevada, where the properties of this company are located, was named after him, and the typical prospectors, whose sturdy qualities he described in an article in the September number of this magazine, will undoubtedly feel his loss as much as his more cultured friends in the East. Mr. Clemens was the consulting engineer of the Central Forge Company, of Whitestone, L. I., and his work with that company in the forging of heavy shafts has proved of great value. For some time previous to his illness he had been engaged in a series of exhaustive tests with heavy machine tools, using independent electric motors, and had prepared much important data which he intended to embody in an article for this magazine. The facts gathered demonstrated much economy in power in the use of such motors, and it is hoped that the results of his observations, covering many months, will be found

ERNEST V. CLEMENS.

available for future use. Mr. Clemens was a lover and a shining light of his profession, of art as well as of nature, and a microscopist of more than ordinary ability. To all with whom he came in contact, but especially to those close to him, he was known as the staunchest of friends and the embodiment of all that was manly. At the time of his death he was a member of the American Society of Mechanical Engineers, the American Society of Civil Engineers, the Engineers' Club, the Old Curiosity Club, the Schnorer Club and the Technischer Verein.

Current Topics.

THE general plan of burning pulverized coal is rather a seductive one and numberless attempts have been made for years past to make it yield those advantages—principally that of economy—which its advocates have claimed it to possess. After all, however, very little has been accomplished with it. The latest efforts to bring it into extended, practical use have probably been made in Germany where, according to recent account, the possibility which it suggested of helping to subdue the smoke nuisance has attracted attention, and experiments, it is said, are now being made there to determine how much good can be accomplished with it in this direction. Trials are also being made with it on some of the steamers of the North German Lloyd, but of the results of these much conflicting reports have been given out, so that it is impossible at present to indulge in anything more than mere speculation as to their true nature. The manner in which the dust coal is burned under the boilers of these vessels is described in one of the foreign journals about as follows: In front, and above the firedoor of the furnace, a large iron bucket is fixed, large enough to contain from one to two hundred weights of coal dust. From this bucket the dust falls through an iron pipe on a sieve, which is made to let through a smaller or larger quantity of the dust as desired. From this adjustable sieve the dust passes over some iron bars, arranged so as to form little gullies or furrows, on to iron plates fixed in a sloping position in the interior of the furnace. Toward these a powerful blast of air is directed, which catches the coal dust as it falls from the iron plates, and spreads it through the

whole of the furnace. By this means, it is claimed, complete combustion of the dust is effected, a high temperature is maintained, and the formation of ashes and clinkers is, to a great extent, avoided. One of the drawbacks mentioned is that, for the present at least, the fire must be started in the old way, by means of wood or other combustible, until sufficient steam is generated to set the blowers in operation.

NOTHING is said, however, of several other more serious drawbacks which must yet be overcome before the scheme can be pronounced measurably successful. One of these is the necessity of using an enormous excess of air in the blast which is required to carry the powdered coal into and through the heating chamber, thus unavoidably cooling it and producing in it a cutting or wasting flame. Another is, that however perfect may be the combustion of the inflammable particles of this "mechanical gas," there must still remain the ash particles which, however minute, are incombustible and are distributed broadcast over the furnace, usually to great disadvantage. If to these two obstacles be added the cost of pulverizing the coal, and the difficulty of making the powder impalpable at any cost, a sum total is easily reached which in the past has effectively prevented any commercial success in this method of using coal.

STEAM launches, not to mention those propelled electrically or by oil or vapor engines which more recently have been turned out both here and abroad in large numbers and have come into general use, are, as may be readily imagined, comparatively unknown things in far-away China, though it might have been supposed that foreign enterprise had, long before this, made them more common than they really are. Writing to the Department of State from the Chinese port Ningpo, United States Consul Fowler says that there are vast districts, intersected by thousands of miles of canals and rivers, and harboring many millions of people, and yet there is not a single launch or boat of any kind propelled by other than man or animal power, except a few steam launches that ply between Shanghai and Hangchow, about 150 miles northeast of Ningpo. An immense traffic is, however, carried on in small covered boats, which for their propulsion depend on the tide and the endurance of the native scullers. Evidently, there is here a field which, it would seem, might be profitably developed by American launch builders. Consul Fowler himself has been discussing the benefits of small launches with one of the prominent Chinese officials for the past two years, and has been requested by the latter to supply him with particulars of available boats of that class. If a launch should once be adopted in official quarters and thus, in a measure, receive what would appear to be official sanction, Consul Fowler feels assured that it would not be long before many other orders would follow.

As to the kind of boat suitable for navigation in these inland Chinese waters, it would, according to the information given by Consul Fowler, have to be built very strong, and the propeller would have to be so arranged that it could be hoisted inboard or protected in some way against the ropes which are passed around the stern of the boat while it is being pulled over the "haul over" from a river to a canal, or from a lower to a higher canal level. A "haul over" is nothing more than a sluice-way over part of a river or canal bank sloped for the purpose by masonry or earthwork and covered with wet and slippery clay. A boat to pass over one of these has a rope passed around the stern, and the ends of the rope are wound around a windlass on each side of the sluice. Men then work the windlass on both sides until the boat has been hauled to the ridge, when it is pushed into the water on the other side. There are no locks. Sometimes a boat is dragged across a "haul over" by oxen, but the first method is the common one. The boats also should

occupy little head room so as to be able to pass under the bridges, which are generally very low. With the boats now in use the average distance covered daily is only a little over thirty miles. The canals and rivers are the main roads, and all travel is by boat, so that the introduction of quicker methods of transit would, no doubt, be highly appreciated. Considering the available facts, it would seem that any one of the many different types of oil engine and vapor launches now made would satisfactorily meet the requirements here outlined, being preferable to steam launches chiefly on account of their greater simplicity, ease of management and safety—points of not a little importance when it is borne in mind that the boats would probably be in the hands of unskilled and ignorant natives. American builders, always alive to the importance of new interests, might find it well worth the trouble to follow up Consul Fowler's suggestion and to enter into correspondence with him.

THOSE who seem to think that metal railroad cross ties are, comparatively speaking, innovations whose use is mainly practiced in the older railroad countries in Europe where, true enough, they were first thought of and developed, may be interested in knowing that in Mexico about 150 miles of track are laid on steel ties and have done service for some time. These ties, it is stated, weigh about 124 pounds each, are eight feet three inches long, and are rolled with longitudinal stiffening ribs. Clips, formed by cutting notches near the ends of the sleepers and bending up the metal, are provided to more securely hold the rails. Even these ties, however, do not seem to be the first of the metal variety with which our dreamy Southern neighbors have busied themselves. As long as fourteen years ago, in fact, metal ties of crude design were laid down in Mexico—"pot" sleepers as they were not inaptly called, consisting of two cast-iron dishes, oval in form, which were laid inverted in the road ballast and connected by wrought-iron bars, the rails being fastened to the "pots." Many of these, however, have already given way to some of the comparatively light steel forms of the present day, and the exchange is still progressing, so that the early "pot" monstrosities will probably soon be rare indeed.

SPEAKING of metal railroad ties generally, it may not be amiss to recall the fact that they owe their origin to French thought, having been proposed some thirty odd years ago by the French engineer Vautherin. Little was done, however, with the early Vautherin sleeper since it was soon found to but inadequately meet the requirements of actual service and to increase, rather than decrease, as intended, the expense and trouble of track maintenance. About 700 of the ties were laid on one of the small German railroads in the year 1867, but were replaced after a short time by the conventional wooden variety. In 1874 new experiments were made on the same line with somewhat thicker metal ties. About 25,000 of them were put down and, in the main, proved quite satisfactory, some of them probably being still in place, so that the trials, on the whole, may be said to have been successful. Since 1877 the number of metal tie designs has grown apace and for several years past there has been an embarrassing variety from which to choose, each type of tie, of course, being claimed to be the best by its designer, while few of them could boast of actual, time-tried performance as a fair measure of worth. Probably the best results abroad with metal ties have been obtained with what is known as the Heindl tie, which has been in continued successful use for about ten years on several German and Austrian railroads. None of the defects of frequent fracture of the ties themselves and of rapid deterioration of the roadbed on which they are laid—defects which are said to have been prominent on some lines where they were used, notably in Belgium—have there been observed, and the conclusion has been reached on these lines that the superi-

ority of the metal tie over the wooden one is definitely established. On one of the Austrian railroads—the Kaiser Ferdinand Northern—a strictly comparative series of trials were made on a long length of road and extended over the full period of nearly ten years above noted, two parallel sections of line being equipped, one with the Heindl ties and the other with ordinary wooden ones. The traffic conditions on both of the track sections were practically identical, and expense records, which were carefully kept, showed, as the result of the several years of observation, a materially decreased expense account for the metal tie section. At the same time the metal ties, after the full period of use, were found to be still practically as good as new, while the competing oak ties were in a much deteriorated state, notwithstanding the fact that they had been treated with chloride of zinc, an admittedly excellent preservative.

EVER since the introduction of the compound engine the question of relative cylinder proportions has been one of periodical discussions, and its importance has been added to not a little by the later development of the triple-expansion engine in which the sizes of the cylinders adopted by different builders vary still more considerably than in the compound type. The proper proportions of the cylinders depend to an appreciable extent on the total ratio of expansion adopted, and the latter, in turn, depends upon the initial steam pressure used. Still, there is a very wide discrepancy in the dimensions of cylinders chosen for even the same boiler pressures by various designers. From figures recently gone over and bearing principally on English practice, it appears that in one instance a firm, working with a 150-pound boiler pressure, use a ratio of low-pressure to high-pressure cylinder of 6.7, while another firm, for the same pressure, adopt in one case a ratio of 8, and in others, ratios of from 6.2 to 6.8. In the case of one much-spoken-of English steamship the boiler pressure is 115 pounds, and the ratio of high-pressure cylinder to low-pressure cylinder is 5.4. With 140-pound boiler pressure, one eminent firm adopts a ratio of 6.1, and another, with a boiler pressure of 135 pounds, makes the ratio 6.4. Of course some variations in practice are to be expected, but they cannot all be right. Evidently rule-of-thumb work is largely predominant in the matter and the cylinder ratio problem is yet far from having been rationally solved.

THE Serve boiler tube, which was first brought out in Europe a few years ago, and the peculiarity of which consists in having internal ribs running lengthwise, seems to have already well borne out the claims made for it in point of economical performance over the ordinary plain boiler tube, which it resembles exactly, so far as external appearance goes. At any rate, its use is steadily growing, and among its advocates are some of the largest steam users both here and abroad—a circumstance which affords probably the best indication of its value. One of the most recent applications of the tube has been made in connection with some of the fast locomotives of the Paris, Lyons and Mediterranean Railroad, in France, the object sought having been the reduction of weight of the engines without sacrificing steaming capacity, and, from published French accounts, the results appear to have been all that could be desired. The use of the tubes permitted shortening of the boilers without detracting from their evaporative power, as carefully conducted trials are said to have shown, and it seems not unlikely that the advantages thus secured will be followed up by rebuilding some of the other locomotives belonging to the road in question. A measure of what may be accomplished with the Serve tubes in the way of increased evaporative performance was furnished by a series of comparative boiler tests with both natural and forced draughts made in this country a year or two ago. A vertical boiler was

used in these trials, one set being made with plain tubes in place, and another after the ordinary tubes had been replaced by the ribbed variety. With natural draught, the number of pounds of water evaporated per pound of coal was, with the plain tubes, 5.08, and with the ribbed tubes, 8.5 ; with a forced draught of one-half inch of water the evaporative powers figured out, respectively, 5.98 and 7.6 ; and with a forced draught of seven-eighth inch of water they were 4.68 and 6.74.

IN a paper presented at the recent International Engineering Congress at Chicago, Mr. A. E. Hunt proposed a method of testing structural materials which he recommended for general adaption in place of the well-established, older ones, followed both in the United States and Europe. The proposed method consists in punching or otherwise shearing, cutting or drifting pieces of a given thickness of metal, and comparing the "force" required in this work with that required to treat standard pieces in a similar manner. The comparison, Mr. Hunt further explained, can be similarly made with the "work" done, or factors of the work exerted therein at different stages of the punching, cutting or drifting operations, with results obtained in treating standard pieces in a similar manner. Mr. Hunt introduced his subject by enumerating what he called "methods in vogue of testing structural steel," and in this list included the drop test and a hobby of his own called the "drifting" test. The latter is practically used by him alone, and is not at all recognized by any experts in testing materials, being so indefinite and inaccurate as to be of no value to the "structural engineer." The drop test, on the other hand, is classed with those in ordinary use in spite of the fact that it is not employed in this country or in any other in testing structural steel ; that it is still under investigation; and that, although formerly used in inspecting rails, has been practically abandoned.

MR. HUNT failed to explain the relation of hardnesses of the punch and die and that of the material tested, and their effect on the results obtained, and seems to have completely forgotten that the most important factor in his test apparatus is the compressibility of the punch as compared with that of the material. Nothing is said of the gradual change of form of punches and dies which begin with the first test and increase with every following one. There is no examination of the possible effect of different proportions of punch and die on the test results when testing material of varying thickness. The very indefiniteness of the test has been construed into a virtue, as it does not enable engineers to draw limits closely, which latter Mr. Hunt considers improper. He appears to overlook the fact that this same test with numerous refinements has been proposed repeatedly in Europe, and each time has been promptly and almost unanimously rejected by all who had a right to an authoritative opinion. Of even the most important advantage, however, which Mr. Hunt claims for the method, namely, rapidity, he fails utterly to demonstrate the existence. It is simple enough to say that other tests now in common use are apt to delay work and cause annoyance in mills working on time contracts ; but this is far from proving that a punching test, which would be made, probably in the shops, where, alone, the necessary apparatus could be conveniently kept in good condition, would not cause even much greater delays. The only purpose for which the punching test can be used to advantage is to determine uniformity of a number of similar pieces of material. As a means of obtaining precise knowledge of the properties and qualities of a material, however, for which purpose alone tests now in common use have been gradually developed, it is decidedly not to be seriously considered.

NOT a long while after the completion of some of the electric street railroads now in operation in different large cities, complaints began to be made of

the apparently mysterious destruction of gas and water pipes, telephone cables, in fact, of almost all kinds of buried metal work. The destruction was in the form of pitting or corrosion, and in due course of time was ascribed to the action of the electric railroad currents, being what has since been termed destruction by electrolysis, the underground return currents from the electric cars entering and leaving adjacent metal work at convenient points, using it, in part, as a conductor back to the main electric generating station. In order to understand more clearly why these currents should take such devious paths back to their starting point, it may not be amiss to briefly consider the construction of the generally used single-trolley system lines. These consist primarily, as is pretty well known, of the trolley wire, or main overhead conductor. The electric current from the generating station is fed into this wire through a number of intermediate connections, passes along the line of the road and is taken off, in part, at various points by the trolley arms on the cars. From these it proceeds through wires concealed in the cars to the motors underneath the car bodies, through the motors and into the street rails, through which it is designed to go back to the generating stations, thus making a complete circuit. In some cases the rails are connected by copper tie wires soldered to them at the joints. In other cases, what is known as a supplementary wire is used, consisting of an unbroken conductor running from the extreme end of the line back to the power station. At each joint on both rails wires are soldered which are also soldered to the supplementary wire, thus making, as before, a complete metallic circuit for the return of the current to the generating station. In general, however, these return circuits are barely sufficient to accommodate the heavy return currents coming from the car motors and, as a consequence, these seek readier means of return by distributing themselves to the surrounding moist earth and metallic conductors other than the conductors proper. There are various points in the lines of gas and water pipes and other underground conductors where the electric currents enter, and other points again where the currents leave them. At these latter corrosion speedily ensues and there are many instances on record where serious and costly damage has been done by it.

THE telephone companies in different cities have been loudest in their complaints against this evil, and the annoying experience of many of them is set forth in an interesting manner in a report on the subject recently submitted to the Mayor of the city of Chicago by Professor Barrett, the city electrician, after a somewhat extensive investigation. The most striking part of Professor Barrett's report consists of a number of photographs of specimens of corroded telephone cables and pipes, obtained from different places and under different conditions. Fifteen specimens altogether are illustrated, and show in a most tangible manner what may be done by electrolytic action in the way of destruction. One of the specimens is of special interest as illustrating what must often take place at points of high resistance in buried conductors. It consists of two coupled pieces of gas pipe, in which the high resistance at the joint was probably due to the red lead and oil used for the purpose of sealing. Owing to this resistance, a portion of the current which the pipe was carrying was shunted through the surrounding moist earth either to the coupling or section of pipe beyond, thereby causing the destruction of one of the pipes close to the coupling. A large number of electrolytic experiments were carried out by Professor Barrett, showing that not relatively high-tension currents alone, but even those of extremely low potentiality cause rapid corrosion of the metals attacked. In many cases iron and lead were destroyed under the conditions encountered in the underground systems, at potentials considerably under half a volt.